Understanding the psychological factors influencing hospital patients' and visitors' hand hygiene behavior

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vorgelegt von
Susanne Gaube
aus Vilsbiburg

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Erstgutachterin: Prof. Dr. Eva Lermer

Zweitgutachter: Prof. Dr. Peter Fischer

Obergutachterin: Prof. Dr. Gesine Dreisbach

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Preface

This cumulative doctoral thesis presents three studies focused on hospital patients' and visitors' hand hygiene behavior, which is important to reduce the transmission of pathogens that cause healthcare-associated infections. The three studies were published in peer-reviewed journals between 2020 and 2021. The presented thesis consists of the following parts: (1) A brief abstract of studies, followed by the contributions of the co-authors. (2) An overview of the empirical evidence on the burden of healthcare-associated infections and previous research on hand hygiene behavior, as well as the research objective. (3) The three published studies, as the thesis's central part. The papers are reproduced in the accepted pre-print versions with permission from the publishers. However, the individual papers' reference lists are omitted and later integrated into one combined bibliography at the end of the thesis. (4) A comprehensive general discussion of the three studies' results outlines how they contribute to existing literature and their implications for future research and practice.

Abstract

Hundreds of millions of patients are affected by healthcare-associated infections (HAIs) worldwide. Action is needed to prevent the transmission of pathogens causing HAIs to reduce risks to patients' health and burdens on healthcare systems. Hand hygiene is the most effective measure for infection prevention in hospitals. However, hand hygiene among healthcare workers and laypeople is insufficient. Little is known about the facilitators and barriers to patients' and visitors' hand hygiene practices. Therefore, the present research project aimed to identify the central determinants of laypeople's hand hygiene in hospitals. In **Study 1**, a total of *N* = 1,605 patients and visitors were surveyed about their hand hygiene practice in hospitals. Three questionnaires were deployed to test the theoretical models' (TPB, HAPA, and TDF) effectiveness to predict participants' self-reported hand hygiene behavior. Two clusters of variables surfaced as being essential determinants of behavior: self-regulatory and social influence processes. In **Study 2**, visitors' hand hygiene behavior was observed, and they were asked why they did or did not use the hand-rub dispenser in an open-answer format. Overall, *N* = 838 visitors provided explanations, which were consequently coded according to the same theoretical models employed in Study 1. The critical facilitators and barriers were similar to Study 1, implying that future interventions should focus on (1) visibility and accessibility of cleaning products, (2) informing people about their role in infection prevention, and (3) leveraging social influence processes. In **Study 3**, we used the previous studies' insights to design and test an intervention to improve visitors' hand hygiene behavior through persuasive messages. Evidence-based signs were displayed in a hospital lobby, which a total of *N* = 246,098 people entered or left during the field experiment. Two out of seven signs significantly increased visitors' dispenser usage rate. In summary, Study 1 and Study 2 indicate that knowing about the importance of hand hygiene, having easy access to hand hygiene products, establishing a norm for practicing hand hygiene, and being reminded to practice hand hygiene are the critical drivers for good hand hygiene behavior. Study 3 showed that a simple and cost-efficient intervention using these insights could improve hand hygiene behavior in hospitals.

Contributions

Each contributor's specific contribution to the publications is described according to CRediT (Contributor Roles Taxonomy) from the National Information Standards Organization (2020).

Study 1: Hand(y) hygiene insights: Applying three theoretical models to investigate hospital patients' and visitors' hand hygiene behavior

Contributor roles	Contributor names
Conceptualization	Susanne Gaube, Eva Lermer
Data curation	Susanne Gaube
Formal Analysis	Susanne Gaube
Funding acquisition	Not applicable
Investigation	Susanne Gaube
Methodology	Susanne Gaube, Eva Lermer
Project administration	Susanne Gaube
Resources	Susanne Gaube, Peter Fischer
Software	Not applicable
Supervision	Eva Lermer, Peter Fischer
Validation	Susanne Gaube
Visualization	Susanne Gaube
Writing – original draft	Susanne Gaube
Writing – review & editing	Susanne Gaube, Eva Lermer

Study 2: Utilizing behavioral theories to explain hospital visitors' observed hand hygiene behavior

Contributor roles	Contributor names
Conceptualization	Susanne Gaube, Eva Lermer
Data curation	Susanne Gaube
Formal Analysis	Susanne Gaube
Funding acquisition	Not applicable
Investigation	Susanne Gaube
Methodology	Susanne Gaube
Project administration	Susanne Gaube
Resources	Peter Fischer
Software	Not applicable
Supervision	Eva Lermer, Peter Fischer, Wulf Schneider
Validation	Susanne Gaube
Visualization	Susanne Gaube
Writing – original draft	Susanne Gaube
Writing – review & editing	Susanne Gaube, Eva Lermer, Thomas Holzmann, Wulf Schneider

Study 3: The effect of persuasive messages on hospital visitors' hand hygiene behavior

Contributor roles	Contributor names
Conceptualization	Susanne Gaube, Eva Lermer, Peter Fischer, Verena Windl
Data curation	Susanne Gaube, Verena Windl
Formal Analysis	Susanne Gaube
Funding acquisition	Not applicable
Investigation	Susanne Gaube
Methodology	Susanne Gaube
Project administration	Susanne Gaube
Resources	Peter Fischer
Software	Not applicable
Supervision	Eva Lermer, Peter Fischer
Validation	Susanne Gaube, Eva Lermer
Visualization	Susanne Gaube
Writing – original draft	Susanne Gaube
Writing – review & editing	Susanne Gaube, Eva Lermer

Introduction

The Burden of Healthcare-Associated Infections

Healthcare-associated infections (HAIs), also known as *nosocomial infections*, are infections acquired by a patient during the exposure to care in a healthcare facility that were not present or incubating at the time of admission (World Health Organization, 2011). The most common HAIs include ventilator-associated pneumonia, surgical site infections, urinary tract infections, Clostridium difficile infection, and bloodstream infections (Behnke et al., 2017; European Centre for Disease Prevention and Control, 2019; World Health Organization, 2011). The World Health Organization (WHO) claims that HAIs are the most frequent adverse event of care and are a global threat to patients' safety. HAIs can cause severe long-term impairments to patients' physical and mental health, increase mortality rates, and create substantial excess healthcare costs (World Health Organization, 2009, 2011).

According to data from the 2016 and 2017 point prevalence surveys of HAIs in the European Union and European Economic Area, an estimated 6.5% of patients (3.8 million per year) in acute care hospitals had at least one HAI (Suetens, Latour, Kärki, Ricchizzi, Kinross, Moro, Jans, Hopkins, Hansen, & Lyytikäinen, 2018). Each year, approximately 91,130 patients die as a consequence of the most common HAIs in Europe (Cassini et al., 2016). The European Centre for Disease Prevention and Control (2008) estimated that HAIs increase annual healthcare costs by seven billion euros. In Germany, where the present research was conducted, the prevalence of HAIs was 4.6% in 2016, and therefore slightly lower than the European average (Behnke et al., 2017). However, with approximately 478,222 affected patients and 16,245 attributable deaths, the burden of HAIs in Germany is still too high (Zacher et al., 2019).

HAIs are caused by pathogens that can spread over several routes. Endogenous HAIs are caused by pathogens of the patient's body flora. These pathogens colonize the skin and mucous membranes and can enter sterile areas of the body under certain conditions like immunodeficiency or surgery, leading to infections (Gastmeier et al., 2010). Exogenous HAIs

are caused by pathogens transmitted directly from the environment or other people, such as patients, visitors, and healthcare workers (Gastmeier et al., 2010). While some endogenous HAIs are practically impossible to avoid, Gastmeier et al. (2010) claim that almost all exogenous HAIs are preventable. According to a meta-analysis, between 35%-55% of all HAIs are indeed preventable (Schreiber et al., 2018). This shows that infection prevention and control is essential for patient safety. Hand hygiene is considered a crucial measure in preventing HAIs (Vermeil et al., 2019; World Health Organization, 2011).

Effective Hand Hygiene

Contaminated hands are the most common cause of the transmission of pathogens that lead to HAIs (Pittet et al., 2006; World Health Organization, 2009). Hands can become soiled through contact with patients' bodies or objects immediately surrounding the patients. Contaminated hands pose a risk for cross-transmission of pathogens from one person to another if no hand hygiene occurs before and/or after patient contact or if the hand hygiene practice was inadequate (Pittet et al., 2006). Thus, correct hand hygiene is the critical measure to prevent hand cross-transmission of pathogens. The key to effective hand hygiene is to know how and when to perform it.

How: Using an alcohol-based hand rub for cleaning one's hands is the gold standard in healthcare because it is more effective, requires less time, can be made available at the point of care, and causes fewer skin irritations than handwashing with soap and water (Pittet et al., 2009; Vermeil et al., 2019; World Health Organization, 2009). A palmful of alcohol-based hand rub should be used to cover all surfaces on the hand for approximately 30 seconds until the hands feel dry. Only when the hands are visibly dirty or potentially contaminated with spore-forming pathogens should they be cleaned with soap and water (Pittet et al., 2009; Vermeil et al., 2019; World Health Organization, 2009).

When: Healthcare workers' hands are believed to be the most common vehicle for transmitting pathogens causing HAIs (Allegranzi & Pittet, 2009). Therefore, the official WHO guidelines for performing hand hygiene in healthcare settings focus on healthcare workers. The official WHO guidelines require staff to clean their hands in the following situations: 1)

before patient contact; 2) before an antiseptic task; 3) after body fluid exposure risk; 4) after patient contact; and 5) after contact with the patient's surroundings (Pittet et al., 2009; Sax, Allegranzi, et al., 2007; World Health Organization, 2009). The five-moments model has been adopted worldwide. Most healthcare facilities use the model to train their staff and monitor compliance (Pfoh et al., 2013; Sax et al., 2009). While healthcare workers' hand hygiene practice has been extensively scrutinized by infection prevention and control research, patients and hospital visitors have only recently received some attention.

Patients' and Visitors' Role in Spreading HAIs

Several studies found the hands of both patients and hospital visitors were contaminated with pathogens and even with multidrug-resistant organisms that can lead to infections (Birnbach et al., 2015; Cao et al., 2016; Hedin et al., 2012; Istenes et al., 2013; Mody et al., 2019). Consequently, patients and visitors are most likely an underestimated vector for transmitting pathogens causing HAIs (Cheng et al., 2007). However, the effect of patients' and hospital visitors' hand hygiene on rates of HAIs is not well researched. The few studies that investigated this association are reviewed below: Researchers in a psychiatric facility tried to prevent nosocomial outbreaks of respiratory virus infections through administering alcohol-based hand rub several times a day to all patients (Cheng et al., 2007). They found that respiratory virus infections and all other nosocomial infections decreased significantly after the intervention was introduced. Gagne et al. (2010) encouraged patients and their visiting relatives to sanitize their hands twice a day in a community hospital. As a result, nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infections decreased by 51% from the comparative year. Another research team implemented a multi-modal intervention (including staff training, visible reminders, and making hand wipes available) to improve patients' hand hygiene behavior. While the opportunities for patients to perform hand hygiene increased, the rate of *Clostridium difficile* infection decreased significantly (Pokrywka et al., 2017). In summary, these studies are the first to confirm patients' and visitors' role as vectors for pathogen transmission. All three found that improving patients' and visitors' hand hygiene behavior leads to a reduction in HAIs.

Patients' and Visitors' Hand Hygiene Practice in Healthcare Facilities

Despite the evidence that patients and visitors can spread pathogens via their hands, no binding guidelines state when they should perform hand hygiene in healthcare facilities (Landers et al., 2012). However, different recommendations for patients and visitors have been suggested. Landers et al. (2012) proposed the first comprehensive list of nine moments for patient hand hygiene: (1) after using the toilet, bedpan, or commode; (2) when returning to the room after a test or procedure; (3) before eating, drinking, taking medicine, or putting anything in your mouth; (4) when visibly dirty; (5) before touching any breaks in the skin or any care procedures; (6) before dialysis, contact with IV lines or other tubes; (7) after coughing, sneezing, or touching nose or mouth; (8) before interacting with visitors and after they leave; (9) when there is concern about whether hands are clean. While this list includes all moments in which patients are potentially exposed to pathogens, it is too extensive and detailed to communicate and measure effectively. A more practicable list of four critical moments has been proposed by Sunkesula et al. (2015): (1) before and after touching wounds/devices; (2) before eating; (3) after using the restroom; and (4) when entering or leaving the patient room. For hospital visitors, even fewer recommendations regarding hand hygiene are available. Munoz-Price et al. (2015) proposed that all visitors of acute care hospitals should clean their hands (1) before entering and (2) after leaving a patient room. Clear, universally accepted guidelines for patient and visitor hand hygiene in healthcare facilities are needed. These should be consistent with an evidence-based risk assessment of pathogen transmission as well as easy to communicate and remember.

Given the lack of clear guidelines for patients and visitors, it is not surprising that observed hand hygiene rates vary considerably (see Table 1). However, all previous studies have shown that the rates are insufficiently low. Improving patient and visitor hand hygiene behavior should be a priority within infection prevention and control strategies to boost patient safety, especially when taking the effects mentioned above of increasing patients' and visitors' hand hygiene rates on reducing HAIs into account. However, this is not a simple task.

Table 1

Patients' and Visitors' Hand Hygiene Rates Reported in Previous Studies

Study	Target group	Hand hygiene rate
Patarakul et al. (2005)	Visitors	12% before patient contact
Pittz (2009)	Visitors	< 1% at the hospital entrances
Davis (2010)*	Patients and visitors	23% of patients and 35% of visitors before entering a surgical ward
Randle et al. (2010)	Patients and visitors	56% of patients and 57% of visitors according to the WHO five moments model
Filion et al. (2011)*	Visitors	3% in a hospital cafeteria
Birnbach et al. (2012)*	Visitors	< 1% at the hospital entrance
Wolfe and O'Neill (2012)*	Visitors	12% average at the main foyer, ward entrances, and within wards
Fakhry et al. (2012)*	Visitors	11% at entering and exiting the ward
Srigley et al. (2014)	Patients	30% at bathrooms, 39% before meals, 3% at kitchens, 3% of room entries and7% exits
O'Donnell et al. (2015)*	Patients	2% before meals
Sunkesula et al. (2015)*	Patients	10% according to a four moments model
Vaidotas et al. (2015)	Visitors	2% at the hospital entrance
Hobbs et al. (2016)	Visitors	4% at the hospital entrance
King et al. (2016)*	Visitors	15% at the entrance to an intensive care unit
Rashidi et al. (2016)*	Visitors	12% at hospital entrance
Chandonnet et al. (2017)*	Visitors	71% according to the WHO five-moments model in a neonatal intensive care unit
Prasad et al. (2017)	Patients	17% according to their eight moments
Hummel et al. (2019)*	Visitors	4% between their arrival to the unit and entering patient rooms
Lary et al. (2020)*	Patients and visitors	9% patients and 26% visitors according to the WHO five-moments model
Wong et al. (2020)*	Patients and visitors	9% according to a four moments model
El Marjiya Villarreal et al. (2020)*	Visitors	10% between unit entry to exit outside the patient room

Note. Studies included hand hygiene with alcohol-based hand rub and washing with soap and water. *Intervention studies, all hand hygiene rates at the pre-intervention level.

Previous Attempts to Improve Patients' and Visitors' Hand Hygiene Behavior

Behavior change interventions can be defined as "coordinated sets of activities designed to change specified behavior patterns" (Michie et al., 2011, p. 1). Several previous studies tested the effectiveness of behavior change interventions to improve patient and visitor hand hygiene in healthcare facilities. The techniques used in the interventions can be broadly classified into three categories: (1) compulsory hand hygiene executed by staff members; (2) installed signs and reminders; (3) education and assistance.

Only three studies fall into the first category—compulsory hand hygiene executed by staff members. In all three studies, healthcare workers regularly administer alcohol-based hand rub to patients or clean their hands with soap and water (Cheng et al., 2007; Gagne et al., 2010; Pokrywka et al., 2017). Only one of the studies also included visitors as a target group (Gagne et al., 2010). The was no description if these interventions affected patients' and visitors' self-initiated hand hygiene behavior. However, more importantly, in all three papers, a significant reduction in HAIs after implementing mandatory patient and visitor hand hygiene executed by staff members was reported. While these are promising results, it is labor-intensive for healthcare workers to clean patients' and visitors' hands several times a day. Most healthcare facilities do not have the resources to implement such a strategy.

Behavior change campaigns falling in the second category, installed signs and reminders, can be subclassified into analog and electronically supported interventions. In all of the analog studies, visual cues such as posters, tape, and flashlights were placed close to hand-rub dispensers, which should raise visitors' attention and motivate them to clean their hands (Birnbach et al., 2012; Davis, 2010; Filion et al., 2011; King et al., 2016; Rashidi et al., 2016). All but Birnbach et al. (2012) found a significant increase in visitor hand hygiene after introducing the visual cues, and even Birnbach et al. (2012) found an improvement in dispenser usage when combining a sign with the dispenser's optimal location. However, the effect of only using analog visual cues on rates of hand hygiene are relatively moderate. Additionally, the signs might trigger hand hygiene at moments that are not ideal from an infection control perspective (e.g., visitors using the dispenser at the lobby instead of the one in the patient

room before physical contact with a patient). Still, considering how easy and cheap it is to place some analog visual cues to remind people about hand hygiene, they can be considered an efficient and valuable tool within a multi-modal behavior change intervention.

More technologically advanced interventions employing electronically supported reminders have used visual and auditory cues to motivate people to clean their hands. Gaube et al. (2018) installed motion sensor-activated monitors on top of dispensers at patient rooms, which provided normative visual feedback on people's hand hygiene status via emojis. They found a significant rise in dispenser usage but could not distinguish between user-groups. Fakhry et al. (2012) used motion-sensor-activated verbal reminders at hospital ward entrances. The intervention led to a substantial improvement in visitors' observed dispenser use from 11% to 64%. Another study used verbal cues at patients' bedsides as a reminder to clean their hands before meals (Knighton et al., 2018). While the results of the electronically supported interventions are promising, they also come with downsides. All the required structural modifications to the hospital environment were more expensive than simple analog signs. In addition, noise pollution and alert fatigue are significant problems in healthcare facilities (Backman et al., 2017; Xyrichis et al., 2018). Adding even more noise with audible alerts to remind people about hand hygiene is not an ideal strategy.

The majority of published interventions to improve patient and visitor hand hygiene behavior fall into the third category, education and assistance. Usually, interventions within this category are a bundle of behavior change tools. Most of them include training for staff members on how to facilitate and assist in patient hand hygiene, staff reminding patients and visitors to clean their hands, educational materials or training for patients and visitors, and improving the availability of healthcare products for patients and visitors (Ardizzone et al., 2013; El Marjiya Villarreal et al., 2020; Hedin et al., 2012; Lary et al., 2020; Manresa et al., 2020; O'Donnell et al., 2015; Pokrywka et al., 2017; Sunkesula et al., 2015). Some also include visual cues such as posters and stickers (Chandonnet et al., 2017; Cheng et al., 2016; Görig et al., 2019; Wong et al., 2020). Studies that report how hand hygiene rates change (not all such studies do, and several studies only use self-reported measures) after implementing the intervention bundles

usually show substantial improvements. However, all these studies were labor and cost-intensive, making them unsustainable beyond a funded study period. Furthermore, several studies had extremely small sample sizes, which should raise caution when evaluating the interventions' effectiveness.

In summary, studies have shown that different behavior change tools can be implemented to improve patients' and visitors' hand hygiene behavior. Yet no single study has managed to increase patient and visitors' hand hygiene rates to an acceptable level, and the sustainability of many previous interventions is questionable.

How to Enhance the Effectiveness of Behavior Change Interventions?

One reason for this unsatisfactory state of affairs could be that most patient and visitor-centered interventions simply copied strategies that were originally intended to increase hand hygiene compliance among healthcare workers. However, this approach has two drawbacks. First, interventions targeting healthcare workers' hand hygiene compliance generally also show only moderate and short-term effects (see for systematic reviews and meta-analyses: Gould et al., 2017; Luangasanatip et al., 2015; Naikoba & Hayward, 2001; Schweizer et al., 2013; Shlomai et al., 2015). Therefore, healthcare worker-centered interventions are not an ideal model to copy. Second, it cannot be taken for granted that facilitators and barriers to hand hygiene are the same for healthcare workers as for patients and visitors. Research shows that interventions tailored to their target audience are generally more effective in changing peoples' behavior than non-tailored interventions (Baker et al., 2010; Baker et al., 2015; Noar et al., 2007). Tailored interventions are designed and implemented after examining the factors that explain current behavior and reasons for resisting the desired action of a specific target group (Baker et al., 2015). Therefore, the facilitators and barriers to hand hygiene in healthcare facilities should be systematically identified for patients and visitors, and these insights should be used to plan tailored interventions.

Another reason why previous interventions to improve patient and visitor hand hygiene have been less effective than desired could be that most of them were not grounded in behavioral theory. As with tailored as opposed to non-tailored interventions, theory-based

behavior change interventions are generally thought to be more effective than non-theory-based interventions (Albarracín et al., 2005; Dalgetty et al., 2019; Glanz & Bishop, 2010; Taylor et al., 2012). Behavioral theories outline the structural and psychological processes that control human behavior and are essential for changing behavior (Atkins et al., 2017). Therefore, any attempt to understand the facilitators and barriers to good hand hygiene behavior among patients and visitors should be guided by a theoretical model. Behavioral determinants identified through this theory-driven approach can be used to design, implement, and test an intervention.

Identifying Suitable Theoretical Models

The arguments for developing a behavior change intervention grounded in theory are plausible and strong: Besides being considered more effective, utilizing a theory also provides a practicable framework for designing, implementing, evaluating, and improving an intervention when needed. A theory offers a list of antecedents of behavior and usually includes possible mediators influencing the behavior in question (Michie, 2008; Michie & Abraham, 2004). This enables the selection, refinement, and tailoring of appropriate behavior change techniques for an intervention (Davis et al., 2015; Michie, 2008). Also, identifying potential mechanisms affecting a behavior allows one to systematically test how exactly an intervention can make a change (Davis et al., 2015; Michie & Abraham, 2004). According to Michie and Abraham (2004), systematic testing interventions allows investigators to understand whether an unsuccessful intervention failed because it did not affect the proposed mediator or because the proposed mediator itself does not affect the behavior. At a higher level, the use of theory allows one to summarize and interpret existing evidence of how to change behavior, which also helps to refine existing theories or develop new, more useful ones which can then be used as the base for even more effective interventions (Davis et al., 2015; Michie, 2008). For these reasons, the use of theory within a behavior change process is advocated by major government and non-government bodies such as the Medical Research Council (Craig et al., 2008).

However, choosing an appropriate theory can be extremely challenging for researchers and practitioners planning a behavior change intervention. There are two main reasons for this: First, there is an abundance of theories to choose from. In their book 'ABC of Behaviour Change Theories', Michie et al. (2014) describe 83 theories selected as relevant for designing behavior change interventions by an interdisciplinary panel of experts. These theories include more than 1000 constructs, of which many are practically identical, very similar, or overlapping because constructs were renamed or split into multiple facets (Davis et al., 2015; Michie et al., 2005). Second, guidelines on selecting the most appropriate theory for a specific goal are largely missing (Davis et al., 2015; Michie, 2008). Most intervention designers default to using a well-established theory in health behavior research or their personal favorite (Painter et al., 2008), which might lead to selecting an unsuitable theory for a particular case and reduce the potential effectiveness of the planned intervention (Davis et al., 2015). Considering the importance of using theory to identify facilitators and barriers to behavior and design effective change interventions, the task of finding a suitable theoretical framework for patient and visitor hand hygiene in healthcare facilities is crucial and complex.

Theoretical Models Utilized in the Present Research Project

Accordingly, one of the presented research project's main goals was to identify an appropriate theoretical model to find critical facilitators and barriers to patients' and hospital visitors' hand hygiene behavior. After reviewing the literature on previous efforts to utilize theories to understand, predict and improve people's (mostly healthcare workers') hand hygiene behavior, three promising candidates emerged: (1) the Theory of Planned Behavior (TPB, (Ajzen, 1991)); (2) the Health Action Process Approach (HAPA (Schwarzer, 1992, 2001)); and (3) the Theoretical Domains Framework (TDF (Cane et al., 2012; Michie et al., 2005)). All three models have been used to study healthcare workers' hand hygiene behavior and are well-validated, but they differ substantially in complexity and the number of constructs they contain. Below is an introduction to the three theoretical models.

Theory of Planned Behavior: The TPB is considered one of the classic health behavior theories (Sheeran et al., 2017). According to Ajzen (1991), three constructs predict a

person's *intention* to perform a behavior: the person's *attitude towards the behavior*, defined as the degree to which the behavior is viewed positively or negatively; *subjective norm*, which is a person's perceived social pressure to perform or not to perform a behavior; and *perceived behavioral control* (PBC), defined as the subjective assessment of ability to carry out the action in question. The behavioral intention, which is a person's indication of readiness to act, is the direct antecedent for actual behavior, and PBC can also immediately influence behavior. Figure 1 shows the proposed path structure of the TPB.

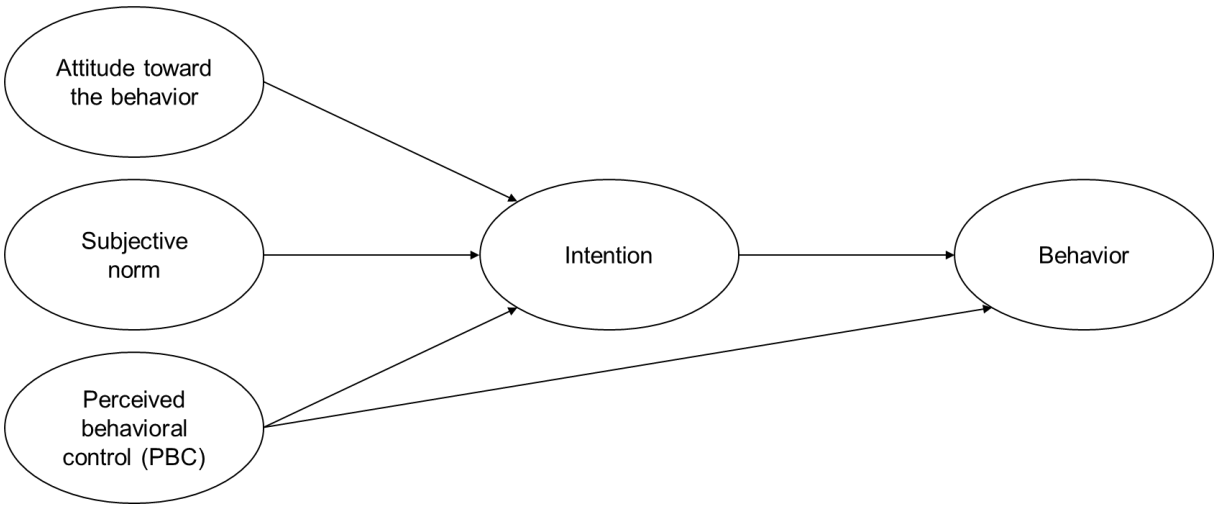

Figure 1. TPB path model.

Godin et al. (2008) claim that the TPB is the most widely-used theory to explain healthcare workers' hand hygiene behavior. Indeed, several studies have utilized TPB-constructs to identify facilitators and barriers to healthcare workers' hand hygiene practice and compliance with guidelines (Eiamsitrakoon et al., 2013; Erasmus et al., 2020; McLaws et al., 2012; O'Boyle et al., 2001; Pessoa-Silva et al., 2005; Pittet et al., 2004; Sax, Uckay, et al., 2007; Whitby et al., 2006). Overall, the TPB seems to be a solid model to explain hand hygiene behavior among healthcare workers. In particular, the constructs of PBC and subjective norms emerged in most studies as crucial factors. However, while the construct of intention generally correlated significantly with observed or self-reported hand hygiene behavior, it usually leaves a substantial proportion of the behavioral variance unexplained. This is known as the 'intention-behavior-gap' (Sheeran, 2002) and has led to criticism of the TPB (e.g., Schwarzer, 2008).

Health Action Process Approach: Schwarzer (1992, 2008) and Schwarzer et al. (2011) tried to overcome the intention-behavior gap by dividing the HAPA model into a *pre-intentional motivational phase* and a *post-intentional volitional phase* (see Figure 2). The three proposed antecedents for intention are *task self-efficacy*, defined as a person's perceived capability to act; *outcome expectancies*, which are beliefs about contingencies of a person's behavior with ensuing outcomes; and *risk perception*, which is an individual's perceived susceptibility to a threat. For the intention to translate into action, it needs to be reinforced. The HAPA model included four of these reinforcement processes: *maintenance and recovery self-efficacy,* defined as a person's beliefs about their ability to overcome barriers during the maintenance period and to regain control after a setback; *action and coping planning*, which are ideas about "when", "where," and "how" to perform the behavior and specific strategies to overcome potential barriers; *barriers and resources*, such as environmental constraints and social support; and *action control,* which encompasses self-regulatory effort, self-monitoring, and awareness of behavioral standards to adjust a behavior (Reyes Fernández et al., 2016; Zhang et al., 2019).

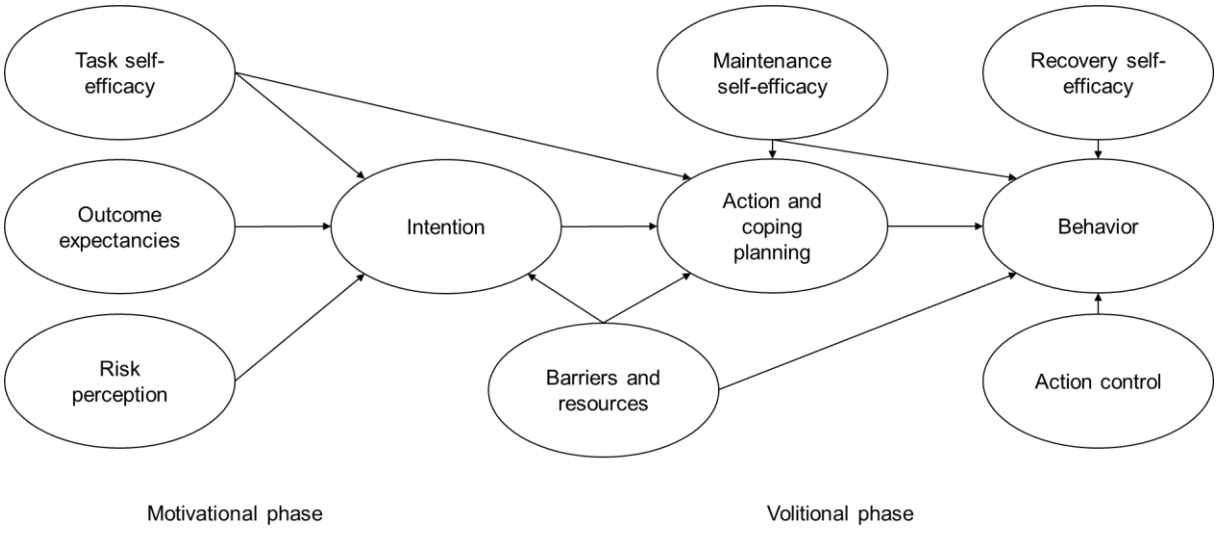

Figure 2. HAPA path model.

The HAPA has been used to study hand hygiene behavior before. In one large study, healthcare workers completed a HAPA-questionnaire to identify critical facilitators and barriers to target in a behavior change intervention (Lutze et al., 2017; von Lengerke et al., 2015).

Overall, a strong belief that hand hygiene prevents pathogen transmission was positively associated with hand hygiene intention (Lutze et al., 2017). A high level of action control was associated with more self-reported hand hygiene compliance among physicians and nurses (von Lengerke et al., 2015). However, it remains unclear how well the entire HAPA model predicts hand hygiene behavior because the questionnaire results have been published in separate papers.

Theoretical Domains Framework: Some researchers argue that using only a single theory is insufficient because the selected theoretical model might lack critical theoretical domains pertinent to explain the behavior in question (Cane et al., 2012; Fuller et al., 2014; Michie et al., 2005). According to an expert consensus, the Theoretical Domains Framework contains the most relevant theoretical constructs (called domains in the TDF) for behavior change (Cane et al., 2012; Michie et al., 2005). The domains and definitions are shown in Table 2. The TDF has been developed to design, implement, and evaluate evidence-based interventions without having to choose a single theory. The framework claims no formal path structure of how the domains interact to determine behavior (Michie et al., 2005), making it easier to test the entire model.

The TDF has also been used to identify facilitators and barriers to hand hygiene behavior in healthcare facilities. Among healthcare workers, the domains of *memory, attention, and decision processes*; *knowledge*; *environmental context and resources*; *social/professional role and identity*; and *beliefs about consequences* have been previously identified as the most important predictors (Fuller et al., 2014; Smith et al., 2019). What sets the TDF apart from TPB and HAPA is that it has been used to investigate patients' hand hygiene behavior (Srigley et al., 2019). The authors reported *knowledge*; *environmental context and resources*; *memory, attention, and decision processes*; and *social influences* as the most relevant for patients' hand hygiene practice.

Table 2

TDF Domains and Definitions

Domain	Definition
Knowledge	State of being familiar with or aware of something.
Skills	Ability to do something which is developed through training and practice.
Social/professional role and identity	Set of beliefs, attitudes, and characteristic behaviors expected of an individual in a social or work setting.
Beliefs about capabilities (self-efficacy)	Subjective perceptions of the capability to perform a behavior in a given setting or to attain desired results.
Beliefs about consequences (anticipated outcomes)	Subjective perceptions of the outcomes and consequences of a behavior in a given setting.
Motivation and goals (intention)	Willingness to exert effort in pursuit of a goal or outcome an individual wants to achieve.
Memory, attention, and decision processes	Ability to retain information, focus on specific aspects of the environment, and choose between alternatives.
Environmental context and resources	Conditions in a situation or an environment that facilitate or hinder the occurrence of a behavior.
Social influences (norms)	Interpersonal processes that facilitate a change in thoughts, feelings, or behavior.
Emotions	A complex reaction pattern by which the individual attempts to deal with a personally significant matter or event.
Behavioral regulations	Processes aimed to manage or change a behavior.
Nature of the behavior	Definition and characteristics of a behavior.

Note. The definitions are based on the original publications (Cane et al., 2012; Michie et al., 2005) and definitions from the American Psychological Associations' Dictionary of Psychology (VandenBos, 2007).

Using theoretical models to identify important barriers and facilitators to behavior should be the first step when planning a behavior change intervention. When designing intervention materials, these barriers and facilitators ought to be addressed.

Designing Effective Intervention Material

As already mentioned, using signs to convey messages about health and safety is a popular intervention strategy to promote hand hygiene (Jenner et al., 2005) and recommended by the German Commission for Hospital Hygiene and Infection Prevention (Kommission für Krankenhaushygiene und Infektionsprävention, 2016). Therefore, we planned an intervention using signs to improve the hand hygiene rate among laypeople in a hospital within the current research project. However, the effectiveness of intervention material can depend on factors such as the target audience, the message's content, its tone, and especially the nature of the

behavior that should be changed (Fishbein & Cappella, 2006; Joffe, 2008; Michie et al., 2011). The last point is critical for highly automatized behaviors such as hand hygiene (Aunger et al., 2010; Diefenbacher, Pfattheicher, et al., 2019; Diefenbacher et al., 2012). For most people, cleaning their hands does not require deliberate thinking, as it is a habit triggered through context (Diefenbacher, Pfattheicher, et al., 2019). Therefore, intervention materials to promote hand sanitation should not focus on cognitively demanding messages explaining the risk of pathogen transmission but rather use influence techniques that trigger an automatic response. Cialdini (2007, 2016) has summarized seven universal principles of influence that often guide human behavior: (1) *Reciprocity* entails that people feel obliged to repay generous acts such as favors, gifts, and services. (2) *Consistency* implies that people want to be consistent in attitudes and actions and abide by existing commitments. (3) *Unity* states that a person is more easily influenced by someone they perceive as part of their in-group. (4) *Social proof* purports that people often decide whether a behavior is appropriate by looking at what others think and do. (5) *Liking* indicates that people we like have greater influence over us than people we dislike or believe to be disagreeable. (6) *Authority* conveys the idea that people obey authorities and follow the lead of experts. (7) *Scarcity* claims that people value scarce resources more than readily available ones. These universal principles have been successfully used to change health and non-health related behaviors (Bushman, 1988; Cialdini, 2007, 2016; Goldstein et al., 2008; Reid et al., 2010; Schultz et al., 2007; Strohmetz et al., 2002). Accordingly, another main goal of the presented research project was to test the effectiveness of intervention using signs designed according to the seven principles of influence on improving hospital visitors' hand hygiene behavior.

The Present Studies

While previous research has shown that insufficient hand hygiene among hospital patients and visitors is a risk factor for the transmission of pathogens causing HAIs, comparatively little is known about what keeps them from or drives them to clean their hands adequately. Therefore, the present research project sets out to identify the most important facilitators and barriers to hand hygiene using a mixed-methods approach and to

experimentally test if an intervention designed according to these findings can improve visitors' behavior. For this purpose, three studies were conducted.

In **Study 1**, a quantitative research approach was employed to address three research questions: (1) What is the most suitable theoretical model to explain patients' and visitors' self-reported hand hygiene practice? (2) What theoretical components are good predictors for hand hygiene behavior? (3) Are the essential determinants of hand hygiene behavior the same for laypeople and healthcare workers? To answer these questions, patients and visitors were surveyed about their hand hygiene practice in hospitals. Three questionnaires, based on the theoretical models TPB, HAPA, and TDF, were deployed.

Reviewing the literature showed that the method (quantitative or qualitative) used to measure the constructs seem to influence which of the constructs emerge as strong predictors for behavior. Therefore, in **Study 2**, a qualitative research approach was employed to answer the following three research questions: (1) Are responses laypeople give for cleaning or not cleaning their hands in an open-answer format similar to answers on a structured questionnaire? (2) What is the most suitable theoretical model to explain visitors' observed hand hygiene behavior? (3) Does visitors' self-reported hand hygiene behavior in hospitals differ from observed behavior? To answer these questions, visitors' hand hygiene behavior in a hospital lobby was observed. Visitors were asked to self-report if they used the hand-rub dispenser and explained why they did or did not in an open-answer format. These explanations were coded according to the same three theoretical models employed in Study 1.

In **Study 3**, the insights gained from the two previous studies were used to plan, implement, and evaluate an intervention to improve visitors' hand hygiene behavior. The intervention material was designed to address the three key learnings: (1) visually drawing attention to the hand-rub dispenser with large signs, (2) informing visitors about their role in infection prevention through the signs' messages; and (3) leveraging social influence processes by using the well-established seven principles of influence: reciprocity, consistency, social proof, unity, liking, authority, and scarcity. The experiment was supposed to answer the following three research questions: (1) Are more visitors using the hand-rub dispenser in the

hospital lobby when a sign is displayed? (2) Are some signs more effective in increasing the dispenser usage rate than others? (3) Does the dispenser usage rate correlate with the number of people entering or leaving the hospital lobby? Accordingly, seven signs were designed, one for each principle. For the 14-week-long field experiment, each was displayed on a large screen for one week directly above the hand-rub dispenser in a hospital lobby. The foot traffic in the lobby and dispenser usage rate was measured with an electronic traffic monitoring system.

Study 1

Hand(y) hygiene insights: Applying three theoretical models to investigate hospital patients' and visitors' hand hygiene behavior

Susanne Gaube, Peter Fischer, and Eva Lermer

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Abstract

Background: Improving hand hygiene in hospitals is the most efficient method to prevent healthcare-associated infections. The hand hygiene behavior of hospital patients and visitors is not well-researched, although they pose a risk for the transmission of pathogens. Therefore, the present study had three aims: (1) Finding a suitable theoretical model to explain patients' and visitors' hand hygiene practice; (2) Identifying important predictors for their hand hygiene behavior; and (3) Comparing the essential determinants of hand hygiene behavior between healthcare professionals from the literature to our non-professional sample.

Methods: In total *N* = 1,605 patients and visitors were surveyed on their hand hygiene practice in hospitals. The employed questionnaires were based on three theoretical models: (1) the Theory of Planned Behavior (TPB); (2) the Health Action Process Approach (HAPA); and (3) the Theoretical Domains Framework (TDF). Structural equation modeling was used to analyze the data. To compare our results to the determinants of healthcare workers' hand hygiene behavior, we searched for studies that used one of the three theoretical models.

Results: Among patients, 52% of the variance in the hand hygiene behavior was accounted for by the TDF domains, 44% by a modified HAPA model, and 40% by the TPB factors. Among visitors, these figures were 59%, 37%, and 55%, respectively. Two clusters of variables surfaced as being essential determinants of behavior: self-regulatory processes and social influence processes. The critical determinants for healthcare professionals' hand hygiene reported in the literature were similar to the findings from our non-professional sample.

Conclusions: The TDF was identified as the most suitable model to explain patients' and visitors' hand hygiene practices. Patients and visitors should be included in existing behavior change intervention strategies. Newly planned interventions should focus on targeting self-regulatory and social influence processes to improve effectiveness.

Keywords: hand hygiene, patients, visitors, TPB, HAPA, TDF

Introduction

Worldwide, healthcare-associated infections pose a severe threat to patients' health and impose massive financial burdens on health systems (World Health Organization, 2011). The European Centre for Disease Prevention and Control estimated that 3.2 million patients were affected by healthcare-associated infections at European acute care hospitals in 2011-2012 (ECDC, 2013). In an earlier report, it was projected that healthcare-associated infections directly cause approximately 31.000 deaths, contribute to another 111.000 deaths, and cost about EUR 7 billion annually (European Centre for Disease Prevention and Control, 2008).

Improving hand hygiene behavior has been confirmed as an efficient method to prevent healthcare-associated infections. Sanitizing hands with an alcohol-based hand rub, which is the World Health Organization's (WHO) gold standard for hospital hand hygiene in most cases, inhibits the spread of pathogens and reduces the risk of infection (Allegranzi & Pittet, 2009; Pittet et al., 2000; World Health Organization, 2009). Contaminated healthcare workers' hands are known to be the most common vehicle for the transmission of pathogens causing healthcare-associated infections (Allegranzi & Pittet, 2009). However, several studies have shown that both patients and hospital visitors carry multidrug-resistant and other pathogenic organisms on their hands as well (Birnbach et al., 2015; Hedin et al., 2012; Istenes et al., 2013). Therefore, non-healthcare professionals are a risk factor for the transmission of pathogens that can lead to infections. Presently, patients' and hospital visitors' hand hygiene behavior is not well researched. Patients and visitors are most likely an underestimated factor in infection prevention (Cheng et al., 2007). In one study, patients and their relatives were encouraged to sanitize their hands twice a day; as a result, methicillin-resistant *Staphylococcus aureus* (MRSA) infections decreased by 51% (Gagne et al., 2010). Similar positive results were found at a psychiatric facility in which patients had to sanitize their hands every four hours to prevent respiratory virus infection outbreaks (Cheng et al., 2007).

Little is known about how often and in what situations patients and visitors sanitize their hands in hospitals. One reason for the deficiency of research on patients' and visitors' hand hygiene could be the lack of universally valid guidelines that indicate when they should sanitize

their hands in healthcare facilities (Landers et al., 2012). Four critical moments for patient hand hygiene have been proposed by one group of authors: (1) before and after touching wounds/medical devices; (2) before eating; (3) after using the restroom; and (4) when entering or leaving the patient room (Sunkesula et al., 2015). Another group of scholars has suggested a more comprehensive list that identifies nine moments for patient hand hygiene, including "after coughing, sneezing, or touching nose or mouth" and "before and after interacting with visitors" (Landers et al., 2012). Visitors should sanitize their hands at least before and after contact with a patient or the patient's surroundings (Munoz-Price et al., 2015). Given the lack of generally accepted guidelines for patients and visitors, it is not surprising that observed hand hygiene rates vary considerably in published studies. Rates range from 0.5% of visitors at a hospital entrance hall (Birnbach et al., 2012) to 56.0% and 57.3% of patients and visitors, respectively, at two hospital wards (Randle et al., 2010). One survey found that the majority of patients claimed to "always" or "usually" clean their hands after toileting (84%) and before eating (72%), but other critical moments were not reported (Srigley et al., 2019). Variations aside, all studies show that there is room for improvement. Therefore, healthcare facilities should focus on the implementation of behavior change interventions aiming to improve the hand hygiene practice of patients and visitors. Theory-based behavior change interventions are considered more effective than others (Albarracín et al., 2005; Dalgetty et al., 2019; Glanz & Bishop, 2010; Taylor et al., 2012), and utilizing theoretical models also provides a practicable framework for designing, implementing, evaluating an intervention. However, choosing an appropriate theory can be challenging for researchers and practitioners planning an intervention. There is an abundance of health-behavior theories, often with overlapping constructs (Davis et al., 2015; Michie et al., 2005). Therefore, the first goal of the present study was to find a theoretical model that effectively explains patients' and visitors' hand hygiene practice and that can be used to design effective behavior change interventions. We focused on three theoretical models: (1) the Theory of Planned Behavior (TPB, (Ajzen, 1991)); (2) the Health Action Process Approach (HAPA (Schwarzer, 1992, 2001)); and (3) the Theoretical Domains Framework (TDF (Cane et al., 2012; Michie et al., 2005)). These models were chosen

because they have been used to study healthcare workers' hand hygiene behavior previously and are well-validated but differ substantially in complexity. Below is an introduction to the three theoretical models.

Theoretical Background

TPB: The Theory of Planned Behavior (TPB) is a classic health behavior theory (Sheeran et al., 2017) and the most widely cited model to explain hand hygiene behavior among healthcare workers (Godin et al., 2008). For the example of hand hygiene, the TPB postulates that a person's *intention* to clean their hands is the immediate antecedent for behavior. Moreover, the person's intention is predicted by three variables: First, by the *attitude towards the behavior*, which is formed by beliefs about the positive and negative outcomes of performing hand hygiene, and the evaluation of these outcomes; second, by the *subjective norm*, which is shaped through perceptions about normative expectations of significant others regarding hand hygiene and a person's motivation to comply with these expectations; and finally, by a person's *perceived behavior control (PBC),* which is formed through beliefs about the ease or difficulty involved in performing hand hygiene (Ajzen, 1991; O'Boyle et al., 2001). A favorable attitude, salient social norm, and high degree of perceived control should lead to the intention to perform hand hygiene. However, research has shown that intention does not always translate into action, a phenomenon known as the 'intention-behavior-gap' (Sheeran, 2002), which is one of the main sources of criticism of the TPB (e.g., Schwarzer, 2008).

HAPA: To overcome the intention-behavior gap, the Health Action Process Approach (HAPA) differentiates between a *pre-intentional motivational phase,* in which intention is formed, and a *post-intentional volition phase* that leads up to action (Schwarzer, 1992, 2008). In the pre-intentional phase, intention has three antecedents: *Risk perception*, which consists of the perceived likelihood of experiencing a negative outcome in relation to the behavior and the perceived severity of of harm arising from the negative outcome; *outcome expectancies*, which is an assessment of the benefits and disadvantages of the action; and *perceived task self-efficacy*, which is the discerned capability of performing the behavior (Schwarzer, 1992, 2008). Regarding hand hygiene, this means a person who perceives the risk of pathogen

transmission as high, expects that hand cleaning reduces this risk, and believes in their capability to adhere to guidelines, would be expected to develop the intention to perform adequate hand hygiene. After the intention is formed, it needs to be reinforced by post-intentional processes. The two main processes are *planning* and, again, *self-efficacy* (Schwarzer, 2008). Two types of planning act as mediators between intention and behavior: *action planning,* which includes details about "when", "where," and "how" to act; and *coping planning,* which comprises strategies on how to overcome anticipated barriers to the action. Post-intentional self-efficacy can be distinguished into two beliefs: *maintenance self-efficacy*, which is comprised of optimistic beliefs about the capability to overcome barriers during the maintenance period; and *recovery self-efficacy*, which represents beliefs about the ability to regain control after a setback. This means that after the intention to perform hand hygiene is formed, the likelihood for it to translate into action increases if the person has a plan for when, where, and how they will clean their hands and how to overcome potential constraints like an empty hand-rub dispenser. The likelihood further increases if the person is optimistic about overcoming barriers and believes that compliant behavior can be restored even after a violation of the guidelines. Further *barriers (e.g., environmental constraints) and resources (e.g., social support)* can influence the intention, planning, and actual behavior. Finally, *action control*, which is comprised of self-regulatory effort, self-monitoring, and awareness of behavioral standards to adjust their behavior, is the last determinant in the volition phase (Reyes Fernández et al., 2016; Zhang et al., 2019).

TDF: Other scholars have argued that focusing on only one theory, such as TPB or HAPA, to explain behavior is too narrow and leaves much variance unexplained (Cane et al., 2012; Fuller et al., 2014). Relying on only one theory has two main drawbacks: First, the researcher or practitioner needs to be able to identify a theory that is relevant to the behavior out of the abundance of existing models. Second, the selected theory might miss critical theoretical domains pertinent to the action (Michie et al., 2005). To overcome these issues, an expert team developed a consensus on which theoretical constructs are relevant for behavior change. The result is known as the Theoretical Domains Framework (TDF): a validated,

integrative framework based on 33 theories and 128 constructs (Cane et al., 2012; Michie et al., 2005). Originally, 12 theoretical domains were identified: (1) *knowledge*; (2) *skills*; (3) *social/professional role and identity*; (4) *beliefs about capabilities (self-efficacy)*; (5) *beliefs about consequences (anticipated outcomes)*; (6) *motivation and goals (intention)*; (7) *memory, attention, and decision processes*; (8) *environmental context and resources*; (9) *social influences (norms)*; (10) *emotions*; (11) *behavioral regulations*; and (12) *nature of behavior* (Michie et al., 2005). In a validation process, the framework was refined (Cane et al., 2012); however, in a subsequent attempt to develop a generic TDF-based questionnaire, scholars argued for keeping the original version (Huijg et al., 2014). The framework was developed to examine the implementation of evidence-based practice, but not to ascertain "the causal processes that link theoretical constructs in a coherent explanation of behavioral regulation or behavioral change" (Michie et al., 2005, p. 31: p.31). For the hand hygiene example, this means that every domain could be relevant for predicting people's behavior, but not all of them have to be. No formal path structure of how the domains interact to determine peoples' behavior is proposed.

Facilitators and Barriers to Hand Hygiene Behavior

Behavioral theories outline structural and psychological processes that can control human behavior and might be essential for changing behavior (Atkins et al., 2017). Consequently, using theoretical models to study hand hygiene behavior can show which model components are the most important facilitators and barriers toward adequate practice. An intervention to improve the behavior should then focus on those specific facilitators and barriers. Therefore, the present study's second goal was to identify critical determinants of patients' and visitors' hand hygiene behavior in hospitals. Previously TPB, HAPA and TDF have been used to identify facilitators and barriers to healthcare workers hand hygiene compliance. Results are reviewed briefly below.

TPB: A series of papers investigating relevant factors for healthcare workers' hand hygiene behavior reported significant correlations between the three pre-intention TPB variables (attitude, norm, and PBC) and self-reported hand hygiene behavior (Eiamsitrakoon

et al., 2013; McLaws et al., 2012; Whitby et al., 2006). In three similar studies, only subjective norm and PBC emerged as relevant predictors for self-reported hand hygiene (O'Boyle et al., 2001; Pessoa-Silva et al., 2005; Sax, Uckay, et al., 2007). At the same time, a survey among medical students found attitude and PBC, but not subjective norm, to influence self-reported compliance (Erasmus et al., 2020). When objectively observing behavior instead of relying on self-reports, one study found that none of the TPB variables but only the intensity of activity in the unit was negatively associated with hand hygiene (O'Boyle et al., 2001). However, other scholars reported attitude and PBC to predict observed adherence (Eiamsitrakoon et al., 2013), while yet another study found support for all TPB variables (Pittet et al., 2004). Overall, there is evidence for the relevance of all TPB model-components to predict hand hygiene behavior among healthcare workers. However, PBC emerged as being of particular importance. The construct was crucial in the studies that measured and included intention, but it never completely predicted all variance in behavior (O'Boyle et al., 2001; Pittet et al., 2004).

HAPA: The PSYGIENE project implemented an intervention based on the HAPA to improve hand hygiene compliance among healthcare workers (von Lengerke et al., 2017). Healthcare workers completed a HAPA-based questionnaire to identify the relevant targets for the intervention. The results showed that a strong belief among staff members that hand hygiene prevents pathogen transmission was associated with high self-efficacy, high positive outcome expectations, and a strong intention to perform hand hygiene (Lutze et al., 2017). Social resources in the form of cooperation at the ward, maintenance self-efficacy, and action control were significant predictors for self-reported hand hygiene compliance among physicians. Among nurses, only action control was significantly associated with hand hygiene behavior (von Lengerke et al., 2015). These results indicate that post-intentional factors might play a role in overcoming the intention-behavior gap. They also show that relevant factors for engaging in a behavior can vary between target groups. Due to the project's methodology of assessing hand hygiene behavior, it had to remain unclear how much variance in hand hygiene can be explained by the entire HAPA model.

One longitudinal study examined motivational and volitional factors for people's handwashing, albeit outside the healthcare context (Reyes Fernández et al., 2016). They found support for the HAPA model but did not include the variables of risk perception nor barriers and resources. Self-efficacy and outcome expectancies were associated with handwashing intention. Intention, action, and coping planning were indirectly associated with handwashing via action control. However, it remains unclear if these results will translate to hand hygiene behavior in hospitals.

TDF: One study examined 'real-time' explanations for non-compliance with hand hygiene guidelines reported by healthcare staff (Fuller et al., 2014) which were then coded according to the TDF. More than three-quarters of the explanations came from 3 of the 12 domains. Among these 42% belonged to the memory, attention, and decision processes domain (i.e., forgetting, being distracted or prioritizing another task), followed by 26% for the domain knowledge (i.e., lack of knowledge about guidelines), and 9% for the domain environmental context and resources (i.e., lack of time or availability of products).

Two surveys among healthcare care workers identified social/professional role and identity (i.e., what is expected of healthcare professionals), beliefs about consequences (i.e., transmission risks), and knowledge as the most important facilitators of adequate hand hygiene (Smith et al., 2019). They also found that environmental context (i.e., time pressure, workload, and environmental controls); memory, attention, and decision processes; and beliefs about consequences to be the main barriers for compliance (Smith et al., 2019). Another study developed and validated a TDF-based questionnaire to assess the facilitators and barriers to hand hygiene behavior among healthcare workers (Dyson et al., 2013). The authors reported that participants' self-reported hand hygiene compliance correlated with all the TDF domains measured with the instrument. So far, only one study looked at patients' hand hygiene behavior using qualitative data from a survey and interviews, and coded the responses according to the TDF (Srigley et al., 2019). The results indicat that the four most relevant domains for patients' hand hygiene behavior are knowledge and skills, environmental context and resources, memory, attention, and decision processes, and social influences (i.e., social norms). It is

noteworthy that forgetfulness was identified as a primary barrier for adequate hand hygiene in all three TDF-studies. However, memory and attention processes are not even included in the TPB and HAPA. This finding backs the concern that critical theoretical domains might be overlooked when relying solely on one model (2005).

The third goal of the present study was to examine whether the same variables determine both healthcare professionals' and non-professionals' hand hygiene behavior, which is important for planning and designing interventions. Hitherto, interventions to improve hand hygiene among patients and visitors simply copied strategies used to increase hand hygiene compliance among healthcare workers. However, it cannot be taken for granted that determinants for hand hygiene are the same for both groups. Research showed that interventions tailored to its target audience are generally more effective in changing peoples' behavior than non-tailored interventions (Baker et al., 2010; Baker et al., 2015; Noar et al., 2007).

Summary of Research Aims

To sum up, the scope of the present paper is threefold: (1) to identify the model that can explain the most variance in hospital patients' and visitors' self-reported hand hygiene behavior; (2) to find critical determinants of patients' and visitors' self-reported hand hygiene behavior; and finally, (3) to qualitatively compare the essential determinants of hand hygiene behavior in hospitals between healthcare professionals and non-professionals. To address aims (1) and (2), we conducted surveys among hospital patients and visitors using structured questionnaires designed according to three theoretical models (TPB, HAPA, and TDF) and analyzed the data. To accomplish aim (3), we qualitatively compared our results to findings from published studies that used the same three theoretical models to study hand hygiene behavior in hospitals. The results of the present study should help hospital hygiene practitioners design and evaluate future interventions to improve patients' and visitors' hand hygiene behavior in hospitals and, in turn, improve patient safety.

Methods

Survey: Participants

Overall, the data of *N* = 1,605 patients and visitors recruited in four German hospitals were analyzed for the present study. Participants missing more than 30% of the survey items were excluded from the analysis. Thus, the data from 845 patients (age ranged 18 to 93 years; *M* = 55.72, *SD* = 16.78; 51.13% female) and 760 visitors (age ranged 18 to 91 years; *M* = 50.10, *SD* = 16.48; 56.91% female) were included in the analysis. Overall, 19 people did not report their gender, and 37 did not report their age. All participants were informed about the purpose of the study and gave informed consent. The University's Research Ethics Committee waived the requirement for a full ethical review of the study because it was classified as low risk. The study was approved by the executive clinic management of each of the four hospitals in which the survey was conducted.

Survey: Design and Procedure

The study followed a cross-sectional design. Visitors were approached in the hospitals' lobbies, while patients were approached in their rooms and asked to participate in the survey. The wards for the patient survey were pre-selected to ensure a diverse mix of patients. Units covered a broad range of the medical spectrum except for pediatric and palliative wards. The survey was conducted from December 2017 to November 2019. Subjects were randomly assigned to one questionnaire (TPB, HAPA, or TDF). Participants were asked to complete the survey at the hospital and hand it back to the investigators or to a nurse at the unit.

Survey: Materials

The first section of all questionnaires was identical both for visitors and patients. It included information about the purpose of the study, instructions, and demographic questions. The questionnaires for the visitors included two items about their typical hand hygiene behavior in a hospital. The two items assessed whether they usually sanitize their hands (1) before and (2) after contact with a patient on a 5-point scale adopted from previous research (von Lengerke et al., 2015) ranging from 1 (*always*) to 5 (*rarely*). These two moments were chosen as the dependent variable because they are suggested in the literature (Munoz-Price et al.,

2015). Moreover, one of the hospitals in which the survey was conducted placed these indications in their guidelines for visitors.

The patient questionnaire included eight items about patients' typical hand hygiene behavior at the hospital at the following moments: (1) after entering and (2) before leaving the patient room, (3) before eating, (4) after using the restroom, (5) before and after touching wounds or medical devices, (6) before and after contact with mucous membranes, (7) after coughing or sneezing, and (8) before entering a high-risk area such as an intensive care unit. These eight indications were selected as the dependent variable because they are suggested in the literature (Landers et al., 2012). Again, one of the hospitals in which the survey was conducted placed these indications in their guidelines for patients. The behavioral variables were assessed on a 6-point scale ranging from 1 (*always*) to 6 (*never*). The sixth option was included in the patient survey after a few participants in the precursor visitor survey mentioned there should be a *never* answer option.

All questionnaire items afterward varied depending on the theoretical model. The structure of the patient and visitor questionnaires was the same but adjusted for the target group. S1 Table includes the constructs of each questionnaire, example items, numbers of items included in each scale, scale means and standard errors, Cronbach's alphas, and inter-item correlation for each scale and target group.

TPB: There is no standardized TPB-questionnaire because the theory's author recommends constructing a new set of questions suitable for the specific behavior and population of interest. Therefore, our TPB-questionnaire was constructed according to a manual, as suggested in the literature (Francis et al., 2004). All items were developed in English to match the manual's recommendations, and we used forward and backward translation to maintain conceptual equivalence of the questionnaire in German. All items were pre-tested with 21 people from the general public to ensure comprehensibility and face-validity and were modified when necessary. The instrument used among visitors included 42 TPB-items and the one used among patients contained 67 TPB-items. To ensure construct validity, a Confirmatory Factor Analysis (CFA) was performed for each target group to ensure that all

items included in the scales to measure the TPB model's latent variables had at least a standardized factor loading of 0.40. Items with lower standardized factor loadings were dropped, leaving 18 TPB-items among visitors and 45 among patients. The data fit well with the original four-factor TPB structure.

HAPA: The items for the HAPA-questionnaire were adopted from the PSYGIENE project's HAPA-survey (von Lengerke et al., 2016), which they had pre-tested by an independent institute. We reached out to the corresponding authors to gain access to the original German items and adjusted the questions to fit our target group and behavior. All items were pre-tested with 15 people. The visitor questionnaire contained 35 HAPA-items and the patient questionnaire contained 50 HAPA-items. Again, a CFA was performed for each target group to ensure that all items included in the scales to measure the latent variables of the HAPA models have at least a standardized factor loading of 0.40. According to the CFAs, risk perception did not load onto a single factor but should be separated into *perceived likelihood* and *perceived severity*. Among visitors, the items for the perceived likelihood variable did not load well on a factor. Therefore, we selected the most representative item to include in the model. Additionally, outcome expectancies had to be divided into positive and negative outcome expectancies, while all self-efficacy items loaded on a single factor among both groups. The resource- and inverted-barrier-items did not load on a single factor, and the barrier-items also did not load well on a separate factor. Therefore, the barriers-construct was dropped in both groups. In total, 25 items among visitors and 42 among patients were used to build the HAPA scales. The data fit sufficiently well with the suggested HAPA structure.

TDF: Finally, the items for the TDF-survey were adopted from a questionnaire to investigate the barriers and levers to healthcare workers' hand hygiene behavior based on the TDF (Dyson et al., 2013). The authors developed and validated the TDF-instrument in iterative, multistep processes. Their questionnaire combined the knowledge and skills domains and dropped the nature of behavior domain. We adjusted the items to fit our target sample and behavior and used forward and backward translation to produce a German version. All items were pre-tested with 19 people from the general public. The visitor instrument consisted of 39

TDF-items, and the patient survey included 58 TDF-items. Again, CFAs for each target group were performed to ensure that all items included in the scales to measure the latent variables in the TDF models have at least a standardized factor loading of 0.40. Items with lower standardized factor loadings were dropped leaving 31 TDF-items for visitors and 46 items for patients. Among visitors, the items to measure the environmental context and resources domain did not load well on a factor; therefore, we selected the most representative item to include in the model. Overall, the data fit sufficiently well with the suggested 10-factor structure.

Survey: Data Analysis

All analyses were done in *R* version 3.5.3. The path analyses were performed using the package *lavaan* version 0.6-3 (Rosseel, 2012). The models were fitted using a robust maximum likelihood estimation (MLF), accounting for some non-normality in the data with full information maximum likelihood (FIML) for missing data.

We defaulted to using the most commonly reported indexes and relied on cut-off levels for a good model fit suggested in the literature (e.g., Hu & Bentler, 1999; Schreiber et al., 2006): χ^2/df ≤ *2 to 3,* Root Mean Square Error of Approximation (RMSEA) < .06 to .08 with confidence intervals, Standardized Root Mean Square Residual (SRMR) ≤ .08, Comparative Fit Index (CFI) ≥ .95, and Tucker Lewis Index (TLI) ≥ .95. Also, we used the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for model comparison, where the rule 'the smaller, the better' applies. If the majority of these fit indexes imply a good fit, we consider the model to fit the data well. To address the first research aim, we compared the model fit indices and the amount of variance in self-reported hand hygiene behavior explained by each theoretical model among both hospital patients and visitors. To attain the second research objective, we tested which variables of the three theoretical models correlate statistically significantly with self-reported hand hygiene behavior or intention among both target groups. The study's pre-registration, data, and R-script will be made available online upon publication: https://osf.io/m2v56/

Qualitative Comparison: Search Strategy and Eligibility Criteria

To address the third and final research aim, we conducted a literature search on Google Scholar, PsycINFO, and Web of Science from the year 2000 up to March 2020 for relevant articles in the English language. Additionally, the reference lists of eligible publications were screened. We considered any article that measured the variables of at least one of the three theoretical models (TPB, HAPA, and TDF) to study healthcare workers' observed or self-reported hand hygiene behavior. Both quantitative and qualitative studies were included in the review as long as they were published and peer-reviewed. We did not assess the quality of the studies nor their risk of bias. The search strategy included the following keywords: hand hygiene, hand hygiene compliance, hand washing, healthcare workers, healthcare professionals, physicians, nurses, theory of planned behavior, TPB, health action process approach, HAPA, theoretical domains framework, TDF, theory, behavioral theory.

Results

Findings Self-Reported Hand Hygiene Behavior

The patients' mean level of self-reported hand hygiene behavior was $M = 4.08$ ($SD = 1.24$), and the visitors' mean level of self-reported hand hygiene behavior was $M = 3.71$ ($SD = 1.28$). Overall, both patients and visitors reported *frequently* sanitizing their hands in the hospital when averaging their respective indications for hand hygiene (eight indications for patients and two for visitors). Fig 1 shows the participants' responses separated for the indications surveyed.

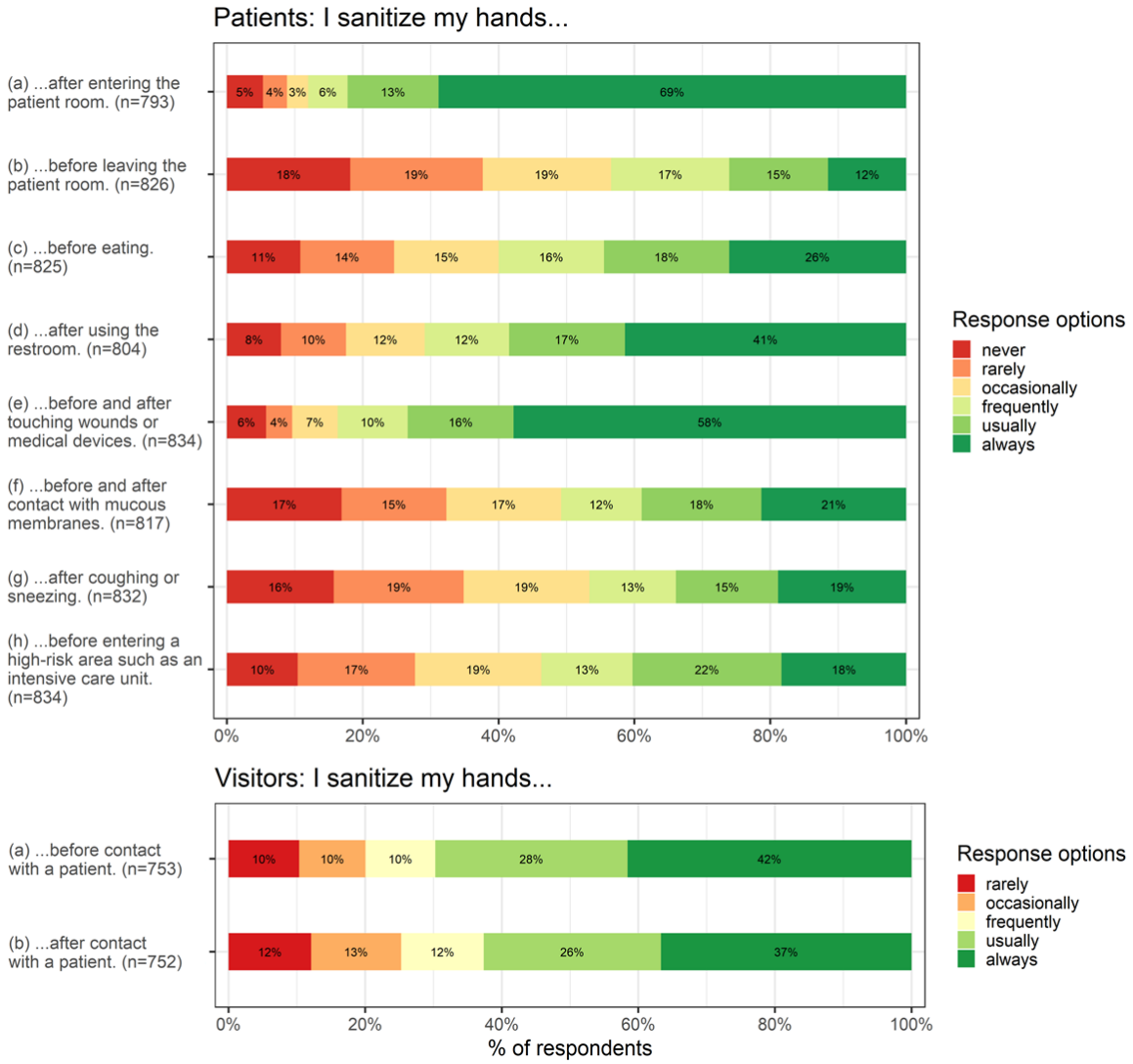

Figure 1. Frequency distribution of self-reported hand hygiene behavior in hospitals.

Findings Aim One: Identifying a Suitable Behavioral Model

TPB: The hypothesized TPB path structure fitted well with the data from both patients (χ^2 = 5.25, df = 2, χ^2/df = 2.63, p = .072, RMSEA = .08 with 90%-CI [.00, .16], SRMR = .02, CFI = .99, and TLI = .97) and visitors (χ^2 = 4.02, df = 2, χ^2/df = 2.01, p = .134, RMSEA = .06 with 90%-CI [.00, .16], SRMR = .02, CFI = .99, and TLI = .98). Attitude, subjective norm, and PBC accounted for 52% of the variance in patients' and 53% of the variance in visitors' behavioral intention. Intention and PBC explained 40% of the variance in self-reported hand hygiene behavior among hospital patients and 55% among hospital visitors.

HAPA: The initially hypothesized HAPA path structure was neither a good fit for the patient data (χ^2 = 83.14, df = 11, χ^2/df = 7.56, p < .001, RMSEA = .16 with 90%-CI [.13, .19],

SRMR = .05, CFI = .80, TLI = .57, AIC = 2375.12, and BIC = 2442.40) nor the visitor data (χ^2 = 173.66, df = 11, χ^2/df = 15.79, *p* = <.001, RMSEA = .24 with 90%-CI [.21, .27], SRMR = .08, CFI = .47, TLI = -.16, AIC = 2735.68, and BIC = 2803.11). Consequently, the models were modified post hoc. Thinking about the nature of hand hygiene behavior, hospital patients most likely do not engage in considerable planning for "when", "where", and "how" to clean their hands, nor for how to overcome any anticipated barriers to performing hand hygiene. Therefore, the planning construct was removed from the models. Additionally, the action control variable was allowed to correlate both with the self-reported hand hygiene behavior as well as intention, since the correlation between these variables was high and the modification improved the model fit substantially. This is also supported by previous research (Reyes Fernández et al., 2016). The new models fitted well with both the patient data (χ^2 = 8.63, df = 4, χ^2/df = 2.16, *p* = .071, RMSEA = .07 with 90%-CI [.00, .13], SRMR = .02, CFI = .99, TLI = .95, AIC = 1332.98, and BIC = 1386.10) and the visitor data (χ^2 = 3.06, df = 4, χ^2/df = 0.77, *p* = .547, RMSEA = <.001 with 90%-CI [.00, .08], SRMR = .01, CFI = 1.00, TLI = 1.00, AIC = 1559.36, and BIC = 1612.60). The new models outperformed the original models significantly (both *p* < .001). Self-efficacy, positive and negative outcome expectancies, risk perception (likelihood and severity), environmental resources, and action control jointly accounted for 52% of the variance in patients' and 49% of the variance in visitors' behavioral intention. Self-efficacy, intention, environmental resources, and action control together explained 44% of the variance in self-reported hand hygiene behavior among hospital patients and 37% among hospital visitors.

TDF: The hypothesized TDF models were just-identified (i.e., equal numbers of variables and parameters with a unique solution). Therefore, the models fitted the data perfectly, and theoretically, there is no need to report fit indices. Nevertheless, we fixed a non-significant parameter (environmental context and resources) to zero to compare the model fit of the three theoretical models. The modified TDF path structure fitted the data very well among both patients (χ^2 = 1.70, df = 1, χ^2/df = 1.70, *p* = .192 RMSEA = .05 with 90%-CI [.00, .18], SRMR = .01, CFI = 1.00, and TLI = 0.96) and visitors (χ^2 = 1.57, df = 1, χ^2/df = 1.57, *p* = .211,

RMSEA = .05 with 90%-CI [.00, .19], SRMR = .01, CFI = 1.00, and TLI = 0.97). The parameter estimates for these two models can be found in the online supplements S2 Table. All social-cognitive variables together explained 52% of the variance in self-reported hand hygiene behavior among patients and 59% among hospital visitors.

Findings Aim Two: Detecting Critical Determinants

TPB: In both samples, all three pre-intentional TPB-variables (attitude, subjective norm, and PBC) significantly correlated with people's intention to sanitize their hands, which in turn correlated significantly with self-reported behavior. Fig 2 shows the parameter estimates with corresponding standard errors and confidence intervals displayed in Table 1.

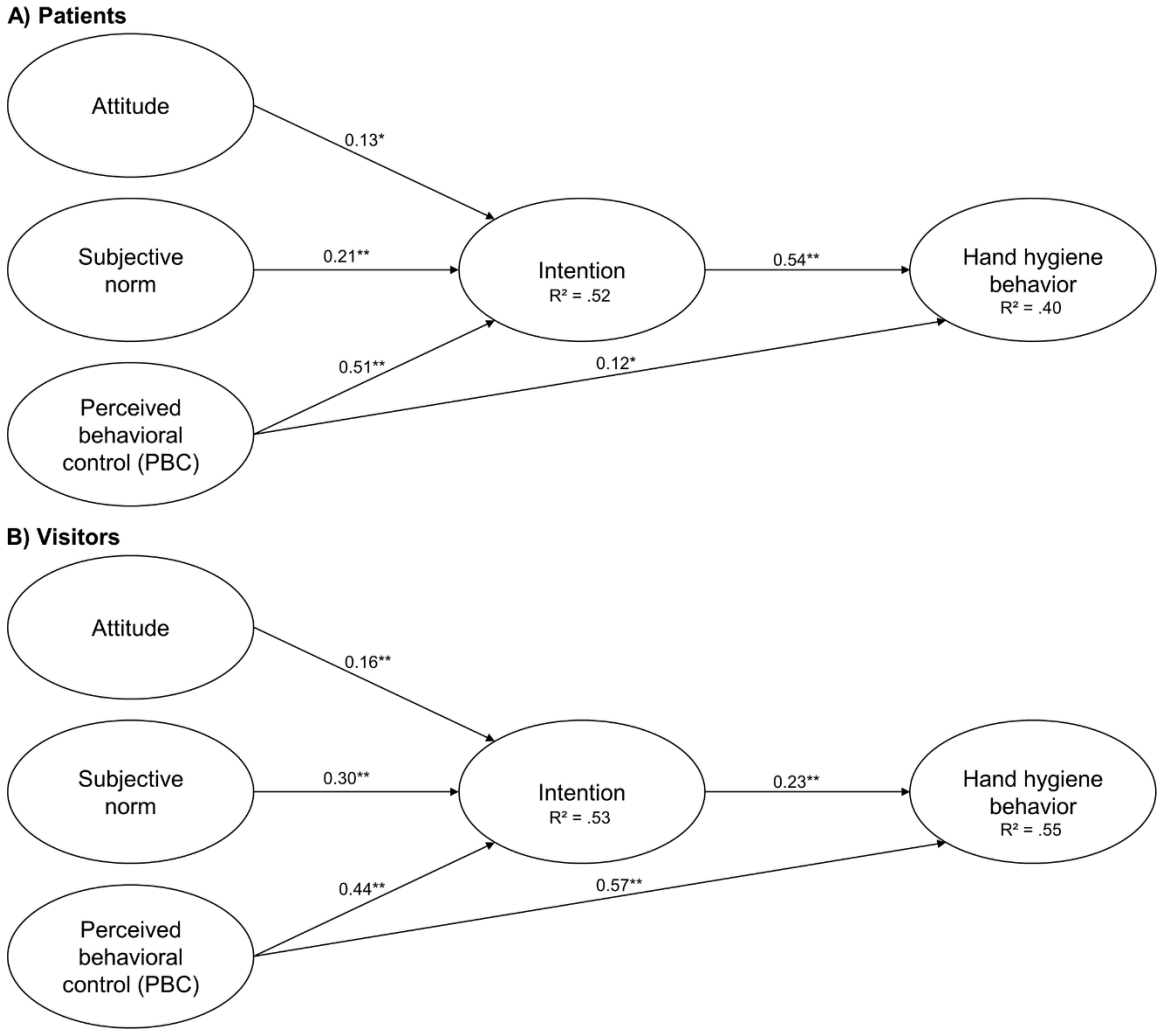

Figure 2. TPB path models with standardized parameter estimates to predict hand hygiene behavior. Note: * $p < .05$, ** $p < .001$, $n_{(total\ patients)} = n_{(used\ patients)} = 286$, $n_{(total\ visitors)} = 251$, $n_{(used\ visitors)} = 248$.

Table 1

Coefficients for the TPB Path Models

						95% CI for β	
	Path	β	*SE*	*z*	*p*	LL	UL
Patients	Attitude → Intention	0.13	0.04	3.04	.002	0.05	0.21
	Subjective Norm → Intention	0.21	0.05	4.46	<.001	0.12	0.30
	PBC → Intention	0.51	0.04	13.05	<.001	0.44	0.59
	Intention → Behavior	0.54	0.05	10.03	<.001	0.44	0.65
	PBC → Behavior	0.12	0.06	2.06	.040	0.01	0.23
Visitors	Attitude → Intention	0.16	0.04	3.77	<.001	0.07	0.24
	Subjective Norm → Intention	0.30	0.05	5.63	<.001	0.20	0.41
	PBC → Intention	0.44	0.05	8.35	<.001	0.33	0.54
	Intention → Behavior	0.23	0.04	5.64	<.001	0.15	0.32
	PBC → Behavior	0.57	0.05	12.35	<.001	0.48	0.66

Note. β = standardized coefficient, *SE* = standard error; *z* = β /*SE*, *p* = probability value, LL = lower limit, UP = upper limit.

HAPA: For patients, self-efficacy, positive outcome expectations, perceived severity of harm, environmental resources, and action control were all significantly correlated with intention. Negative outcome expectations and perceived likelihood of experiencing a negative outcome did not considerably influence intention. Hand hygiene behavior correlated positively with intention and action control. Among visitors, self-control, positive outcome expectations, and action control were significantly correlated with the intention to clean their hands before and after patient contact. The perceived likelihood of an adverse outcome but not the perceived severity was associated with intention. Negative outcome expectations and environmental resources did not influence intention. The only significant correlates for hand hygiene behavior among visitors was intention. Fig 3 shows the standardized parameter estimates for the adjusted HAPA model with corresponding standard errors and confidence intervals displayed in Table 2.

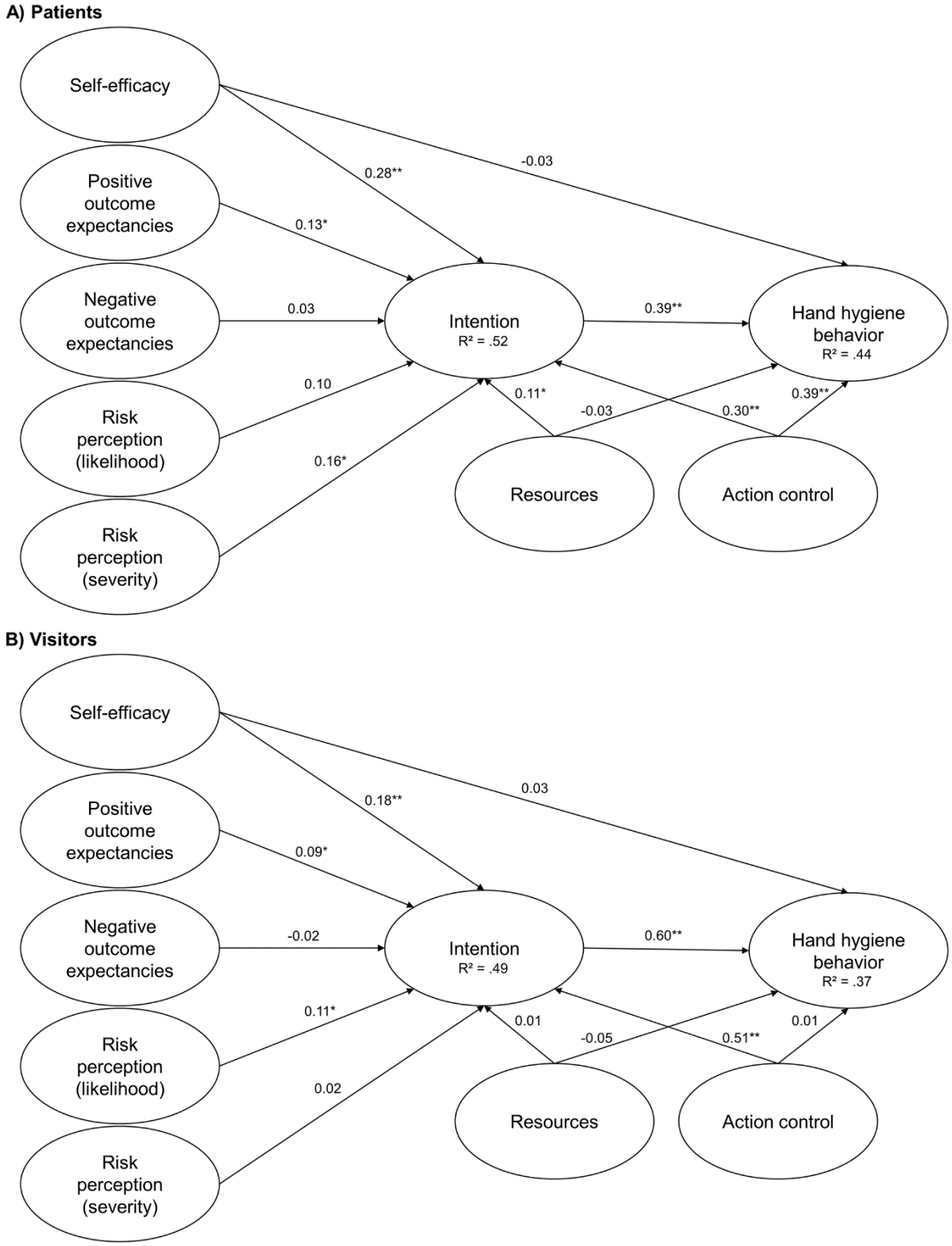

Figure 3. HAPA path models with standardized parameter estimates to predict hand hygiene behavior. Note: * $p < .05$, ** $p < .001$, $n_{(total\ patients)} = 266$, $n_{(used\ patients)} = 255$, $n_{(total\ visitors)} = 264$, $n_{(used\ visitors)} = 257$.

Table 2

Coefficients for the HAPA Path Models

						95% CI for β	
	Path	β	*SE*	*z*	*p*	LL	UL
Patients	Self-Efficacy → Intention	0.28	0.04	7.02	<.001	0.20	0.36
	Pos. Out. Exp. → Intention	0.13	0.06	2.17	.030	0.01	0.25
	Neg. Out. Exp. → Intention	0.03	0.06	0.54	.587	-0.09	0.16
	Likelihood → Intention	0.10	0.06	1.70	.089	-0.01	0.21
	Severity → Intention	0.16	0.05	3.47	.001	0.07	0.25
	Resources → Intention	0.11	0.04	2.37	.018	0.02	0.19
	Action Control → Intention	0.30	0.04	6.77	<.001	0.21	0.38
	Self-Efficacy → Behavior	-0.03	0.05	-0.52	.602	-0.13	0.07
	Intention → Behavior	0.39	0.06	6.36	<.001	0.27	0.51
	Resources → Behavior	-0.03	0.06	-0.48	.632	-0.14	0.08
	Action Control → Behavior	0.39	0.06	6.95	<.001	0.28	0.50
Visitors	Self-Efficacy → Intention	0.18	0.05	3.48	<.001	0.08	0.28
	Pos. Out. Exp. → Intention	0.09	0.04	2.32	.020	0.01	0.17
	Neg. Out. Exp. → Intention	-0.02	0.07	-0.29	.769	-0.15	0.11
	Likelihood → Intention	0.11	0.05	2.37	.018	0.02	0.20
	Severity → Intention	0.02	0.05	0.37	.713	-0.09	0.12
	Resources → Intention	0.01	0.05	0.17	.868	-0.10	0.11
	Action Control → Intention	0.51	0.04	12.50	<.001	0.43	0.59
	Self-Efficacy → Behavior	0.03	0.05	0.54	.592	-0.07	0.12
	Intention → Behavior	0.60	0.07	9.11	<.001	0.47	0.73
	Resources → Behavior	-0.05	0.06	-0.78	.436	-0.16	0.07
	Action Control → Behavior	0.01	0.07	0.11	.911	-0.13	0.15

Note. β = standardized coefficient, SE = standard error; z = β /SE, p = probability value, LL = lower limit, UP = upper limit.

TDF: For patients, role and identity, motivation and goals, memory, attention, and decision processes as well as emotions significantly correlated with self-reported hand hygiene behavior. For visitors, the significant predictors were role and identity, memory, attention, and decision processes, knowledge and skills, as well as emotions. Consequently, the only difference was that instead of motivation and goals, knowledge and skills were associated with behavior, but both variables were only weak predictors. Fig 4 shows the standardized

parameter estimates for the TDF model with corresponding standard errors and confidence intervals displayed in Table 3.

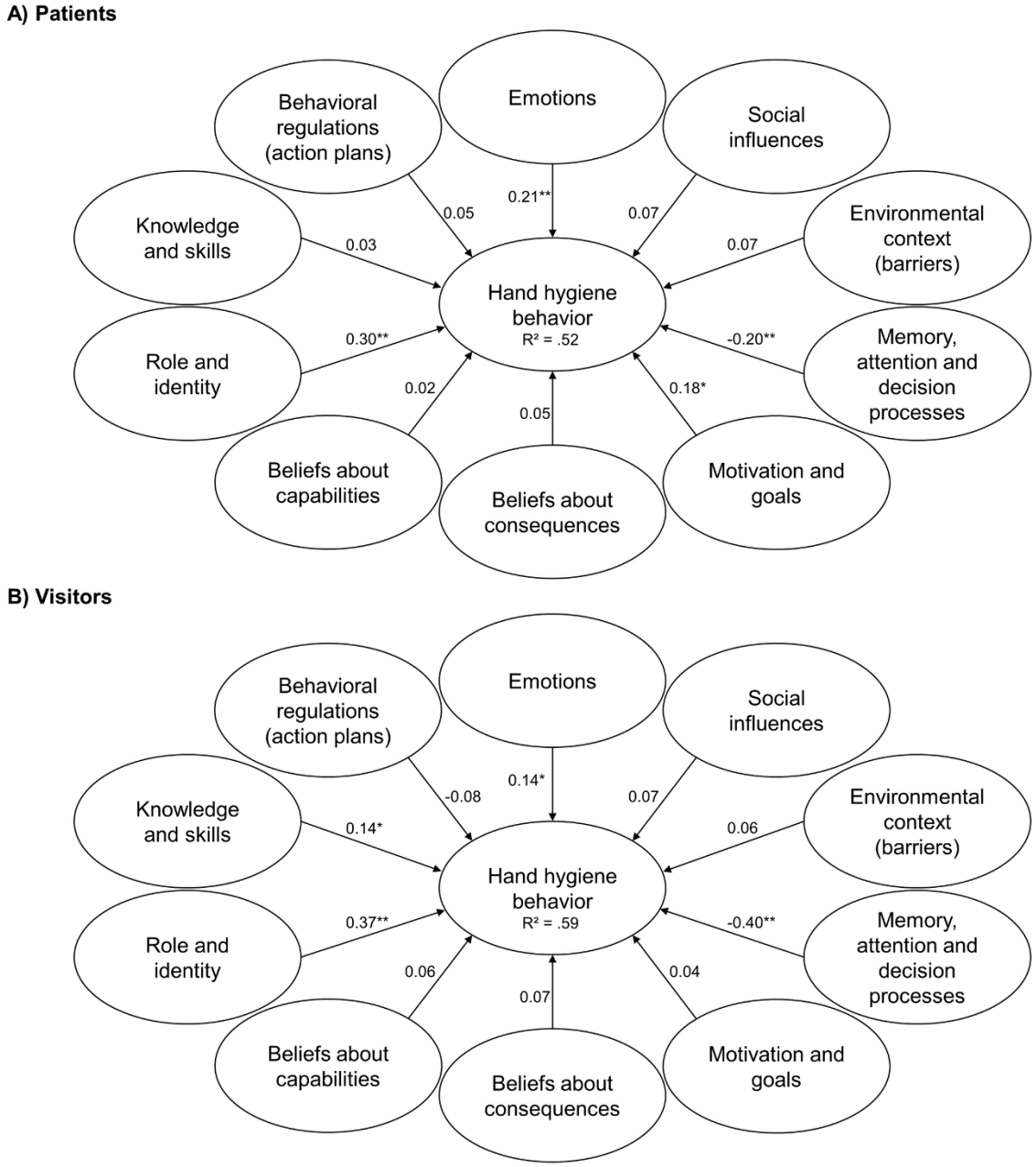

Figure 4. TDF path models with standardized parameter estimates to predict hand hygiene behavior. Note: * $p < .05$, ** $p < .001$, $n_{(total\ patients)} = 293$, $n_{(used\ patients)} = 273$, $n_{(total\ visitors)} = 245$, $n_{(used\ visitors)} = 238$.

Table 3

Coefficients for the TDF Path Models

						95% CI for β	
	Path	β	*SE*	*z*	*p*	LL	UL
Patients	Knowledge/Skills → Behavior	0.03	0.05	0.61	.540	-0.07	0.13
	Role and Identity → Behavior	0.30	0.04	6.81	<.001	0.21	0.38
	Capability → Behavior	0.02	0.05	0.45	.656	-0.08	0.12
	Consequences → Behavior	0.05	0.06	0.81	.415	-0.06	0.15
	Motivation/Goals → Behavior	0.18	0.06	3.05	.002	0.06	0.30
	Memory/Attention → Behavior	-0.20	0.05	-3.82	<.001	-0.31	-0.10
	Environment → Behavior	0.07	0.05	1.33	.184	-0.03	0.16
	Social Influences → Behavior	0.07	0.05	1.34	.179	-0.03	0.17
	Emotions → Behavior	0.21	0.06	3.56	<.001	0.10	0.33
	Beh. Regulations → Behavior	0.05	0.06	0.83	.406	-0.07	0.17
Visitors	Knowledge/Skills → Behavior	0.14	0.05	2.74	.006	0.04	0.23
	Role and Identity → Behavior	0.37	0.06	5.89	<.001	0.25	0.49
	Capability → Behavior	0.06	0.06	1.08	.279	-0.05	0.17
	Consequences → Behavior	0.07	0.05	1.41	.160	-0.03	0.18
	Motivation/Goals → Behavior	0.04	0.05	0.83	.409	-0.06	0.15
	Memory/Attention → Behavior	-0.40	0.05	-7.79	<.001	-0.50	-0.30
	Environment → Behavior	0.06	0.05	1.26	.209	-0.03	0.15
	Social Influences → Behavior	0.07	0.05	1.56	.119	-0.02	0.17
	Emotions → Behavior	0.14	0.06	2.54	.011	0.03	0.25
	Beh. Regulations → Behavior	-0.08	0.05	-1.63	.103	-0.18	0.02

Note. β = standardized coefficient, *SE* = standard error; *z* = β */SE, p* = probability value, LL = lower limit, UP = upper limit.

Findings Aim Three: Comparing Patients and Visitors with Healthcare Professionals

The literature search yielded twelve studies that met the eligibility criteria (see Table 4). Eight studies used the TPB, only one employed the HAPA, and three studies deployed the TDF to identify determinants for hand hygiene behavior among healthcare workers. Most studies included in the qualitative comparison reported self-reported hand hygiene behavior as the outcome measure. In contrast, only two studies used observed hand hygiene compliance, and another two studies described both self-reported and observed behavior. Two

studies included only nursing staff, and another two studies encompassed only medical staff, while the sample of all other studies was comprised of both groups of healthcare workers.

Table 4

Summary of Studies used for the Comparison

Theory	Study	Year	Participants	Outcome variables
TPB	O'Boyle et al.	2001	Nursing staff	Self-reported and observed hand hygiene
	Pittet et al.	2004	Medical staff and medical students	Observed hand hygiene
	Pessoa-Silva et al.	2005	Nursing and medical staff	Self-reported hand hygiene
	Whitby et al.	2006	Nursing staff	Self-reported hand hygiene
	Sax et al.	2007	Nursing and medical staff	Self-reported hand hygiene
	McLaws et al.	2012	Nursing staff, nursing students, and medical students/trainees	Self-reported hand hygiene
	Eiamsitrakoon et al.	2013	Nursing and medical staff	Self-reported and observed hand hygiene
	Erasmus et al.	2020	Medical students	Self-reported hand hygiene
HAPA	von Lengerke et al.	2015	Nursing and medical staff	Self-reported hand hygiene
TDF	Dyson et al.	2013	Nursing, medical, and other healthcare staff	Self-reported hand hygiene
	Fuller et al.	2014	Nursing, medical, and other healthcare staff	Observed hand hygiene
	Smith et al.	2019	Nursing and other healthcare staff	Self-reported hand hygiene

Note. Other healthcare staff includes professions like physiotherapists, personal support workers, and ancillary staff, among others.

TPB: Our results corresponded with several of the published studies in which the three pre-intentional variables attitude, subjective norm, and PBC were shown to be relevant predictors for self-reported hand hygiene compliance among healthcare workers (Eiamsitrakoon et al., 2013; McLaws et al., 2012; Whitby et al., 2006). Other studies found only two out of three pre-intentional variables to be important for self-reported behavior (Erasmus et al., 2020; O'Boyle et al., 2001; Pessoa-Silva et al., 2005; Sax, Uckay, et al., 2007). All studies that used the TPB to predict self-reported hand hygiene behavior identified PBC as being

critical. Studies that used observed hand hygiene behavior as an outcome variable also found significant correlations with PBC (Eiamsitrakoon et al., 2013; Pittet et al., 2004). Only two studies measured intention and showed that the construct was crucial, but it did not predict all variance in behavior, which is known as the 'intention-behavior-gap'. We saw a similar effect in our analysis. An overview of the comparison can be found in Table 5.

HAPA: To our knowledge, only one study connected HAPA variables with hand hygiene behavior among healthcare workers (von Lengerke et al., 2015). This study found that self-reported hand hygiene compliance among physicians was associated with environmental resources, maintenance self-efficacy, and action control. Self-reported behavior among nurses was only linked to action control. The paper did not report the pre-intention HAPA variables (risk-perception, outcome expectancies, and task self-efficacy). When only considering the post-intention variables, the patients' and visitors' results correspond to the findings among healthcare workers. Action control correlated significantly with patients' hand hygiene behavior, and the link between action control and visitors' hand hygiene behavior was mediated through intention.

TDF: Three studies examined the determinants of hand hygiene behavior among healthcare workers using the TDF (Dyson et al., 2013; Fuller et al., 2014; Smith et al., 2019). All three found memory, attention, and decision processes (i.e., forgetting, lack of focus, or prioritizing other tasks) to be among the most crucial barriers to adequate hand hygiene, which is in accordance with our results on the behavior of patients and visitors. A second important determinant for healthcare workers' hand hygiene compliance in all three studies was knowledge. In our analysis of patients and visitors, this factor only correlated with visitors' hand hygiene behavior significantly, and the effect was not very profound. A third domain deemed imperative for healthcare workers' hand hygiene compliance in the published studies was environmental context and resources, which did not emerge in our analysis of patients and visitors as a significant predictor. Two of the three studies identified social/professional role and identity as a central determinant for healthcare workers' hand hygiene behavior, which is corresponds with our results. Finally, we did not find evidence that beliefs about consequences

were a good predictor for hand hygiene behavior among patients and visitors, while two of the three studies that investigated healthcare workers' hand hygiene compliance found that this variable was a relevant predictor of behavior for the studied population.

Table 5

Support for the Association Between Individual Determinants and Hand Hygiene Behavior

		Target group		
Theory	Variable	Patients[1]	Visitors[1]	Healthcare workers[2]
TPB	Attitude	*	**	5/8
	Subjective norm	**	**	7/8
	PBC	**	**	8/8
	Intention	**	**	2/2
HAPA	Self-efficacy	**	**	1/1
	Outcome expectancies	*	*	*Not tested*
	Risk perception	*	*	*Not tested*
	Intention	**	**	*Not tested*
	Resources and barriers	*	ns	1/1
	Action and coping planning	ns	ns	0/1
	Action control	**	**	1/1
TDF	Knowledge and skills	ns	*	3/3
	Social/professional role and identity	**	**	2/3
	Beliefs about capability	ns	ns	1/3
	Beliefs about consequences	ns	ns	2/3
	Motivation and goals	*	ns	1/3
	Memory, attention, decision processes	**	**	3/3
	Environmental context and resources	ns	ns	3/3
	Social influences (norms)	ns	ns	1/3
	Emotions	**	*	1/3
	Behavioral regulations	ns	ns	1/3

Note. [1]Results from the present study; ns = not significant, * $p < .05$, ** $p < .001$ with a link either directly to behavior or intention; [2]Results from previously published work; number of studies that found support for a variable out of total number reviewed (e.g., 5/8 five out of eight studies).

Discussion

Summary Aim One: Identifying a Suitable Behavioral Model

The first goal of the present study was to identify a theoretical model suitable for explaining the self-reported hand hygiene behavior of hospital patients and visitors. This was achieved by conducting a survey in four German hospitals using questionnaires based on the

three theoretical models: TPB, HAPA, and TDF. All three models proved useful for examining self-reported hand hygiene practice in hospitals. Among patients, 52% of the variance in hand hygiene behavior during their hospital stay was accounted for by the TDF domains, 44% by the modified HAPA model, and 40% by the TPB. Among visitors, these figures were 59% (TDF), 37% (HAPA), and 55% (TPB) of explained variance in hand hygiene before and after patient contact.

HAPA: The original HAPA path model did not fit the patient and visitor data well. According to the HAPA model, action and coping planning act as mediators between intention and behavior (Schwarzer, 2008; Schwarzer et al., 2007). However, these planning processes did not emerge as mediators in the present study. Our first assumption on why the planning processes did not fit in the model had to do with the lack of focus on patients' and visitors' hand hygiene behavior for infection prevention. Researchers and hospital hygiene specialists have only recently begun to pay more attention to patients and visitors as a potential vector for transmitting pathogens. Therefore, attempts to include them in the hospital's infection prevention strategy are still at an early stage. Consequently, we expected that many participants would be in the pre-intentional phase of the HAPA model because they might lack awareness that they should clean their hands. The HAPA questionnaire included a state of change item also used in previous research (von Lengerke et al., 2016). Surprisingly, most patients (73.4%) and visitors (80.3%) positioned themselves in the post-intentional action phase. This finding corresponds to their high level of self-reported hand hygiene behavior and indicates that patients and visitors are aware that they should clean their hands regularly in hospitals. However, this finding makes it harder to explain why the planning constructs seemed irrelevant for this target group. A second explanation could lie in the cross-sectional nature of the study. Some of the planning items convey more meaning in longitudinal research, where participants try to change their behavior deliberately. Therefore, the HAPA model should be reexamined within a longitudinal behavior change intervention. A third explanation might be the nature of the behavior, as already mentioned in the results section. Being hospitalized is usually a straining and anxiety-inducing situation for patients and their relatives, during which

hand hygiene might not be a priority for them. Consequently, patients and visitors probably do not plan for “when”, “where”, and “how” to clean their hands, nor for how to overcome barriers. It is intuitively plausible that the planning constructs do not fit in the model for this behavior and target group. Including action and coping planning as determinants for behavior might only be relevant if people are motivated to change. After the modifications to the model, it fits both the patient and visitor data well, but it still explained less variance in the self-reported hand hygiene behavior than the TDF model.

TPB and TDF: The path structure of the TPB and the TDF did not need any changes. TDF was created “to simplify and integrate a plethora of behavior change theories and make theory more accessible to, and usable by, other disciplines” (Cane et al., 2012, p. 2: p.2). It is no causal model of behavior and does not include mediation pathways, which would indicate a causal direction of how its domains are related to each other and the behavior in question. The model fit of a just-identified model with equal numbers of variables and parameters with a unique solution is inevitably perfect, and the results are identical with a linear multiple regression analysis. To compare the fit of the TPB and TDF, we fixed a non-significant parameter to zero. Both the proposed TPB and the TDF model fitted the patient and visitor data very well. When comparing all fit indices, the TDF showed a slightly better fit. Additionally, the TDF explained more variance in self-reported hand hygiene behavior than the TPB in both samples. Thus, it can be concluded that both models are suitable for explaining hand hygiene behavior among hospital patients and visitors. Still, the more comprehensive TDF would be our model of choice to determine barriers and levers related to patients’ and visitors’ hand hygiene in healthcare facilities, and to use as a base for designing interventions.

Summary Aim Two: Detecting Critical Determinants

The second aim of the study was to find critical determinants of patients’ and visitors’ hand hygiene behavior. This was achieved by analyzing the correlations between the proposed factors and identifying the most relevant predictors for self-reported behavior.

TPB: In both samples, all the pre-intentional TPB-variables significantly correlated with people’s intention to sanitize their hands. The data showed that especially PBC played an

essential role. The associations between intention and behavior as well as PBC and behavior were significant in both samples. However, among patients, the indirect effect between PBC and behavior was stronger than the direct effect, while the opposite was true for visitors. This might imply that intention formation is more important for patients than visitors. For visitors, the ease or difficulty of hand hygiene (e.g., access to dispensers) was the most relevant direct predictor for the behavior. But for patients, who have more indications to sanitize their hands throughout the day, the ease or difficulty of cleaning one's hands might lead to the formation of an explicit intention for whether it is worth bothering to engage in the behavior.

HAPA: Patients' intention to sanitize their hands significantly correlated with the variables of self-efficacy, positive outcome expectations, perceived severity of harm, environmental resources, and action control. Self-efficacy and action control had the most substantial effects. Patients' hand hygiene behavior correlated positively with intention and action control. Overall, these results are in line with findings from a previous study that showed self-efficacy and outcome expectancies to be connected with handwashing intention (Reyes Fernández et al., 2016). Likewise, the study reported intention and especially action control to be associated with hand hygiene behavior (Reyes Fernández et al., 2016). Among visitors, self-efficacy, positive outcome expectations, and action control also significantly correlated with the intention. Again, self-efficacy and especially action control had the most substantial effects. Other than the patients, the perceived likelihood but not the perceived severity was associated with intention. The only significant correlates for hand hygiene behavior among visitors was intention. The association between action control and behavior was mediated by intention. While intention was the strongest predictor for both samples' behavior, the intention-behavior gap was not fully bridged by self-efficacy and action control (and planning processes, which did not fit in the model).

TDF: Patients' hand hygiene behavior significantly correlated with the domains of social/professional role and identity; motivation and goals; memory, attention, and decision processes; and emotions. For visitors, the significant predictors were social/professional role and identity; memory, attention, and decision processes; and knowledge and skills; as well as

emotions. The only difference was that instead of motivation and goals, knowledge and skills were associated with visitors' behavior. In both samples, the social/professional role and identity domain had the largest effect on behavior. The memory, attention, and decision processes domain also had a substantial effect on hand hygiene behavior among both patients and visitors. When comparing our results with findings from a Canadian qualitative study that looked at patients' hand hygiene behavior (Srigley et al., 2019), we can see that the memory, attention, and decision processes domain emerged as a critical factor in both studies. The other study identified the social influences domain as an essential factor, while we found the social/professional role and identity domain to be a relevant predictor. The two domains are connected, since both have social norms as an underlying process. More theoretical clarity about the distinction between the two domains might be needed. Finally, in our sample, the environmental context and resources domain was not relevant in either group, but has been identified as an important barrier to patients' hand hygiene behavior in the other study (Srigley et al., 2019). While a lack of products or not recognizing hand rub as such was identified as a problem in the Canadian study, most participants in our sample did not indicate that a lack of resources was an issue. It remains unclear if the healthcare systems or hospitals in which the respective data was collected are responsible for this mismatch.

In conclusion, both the data from the TPB and the HAPA model showed that behavioral intention is a strong but not perfect predictor for self-reported hand hygiene behavior. These results underline the importance of intention formation to explain behavior and facilitate behavior change. However, the findings also show that we need a better understanding of the psychological processes determining intention and leading from intention to action. When looking only at the strongest and most coherent determinants affecting self-reported hand hygiene behavior directly or indirectly via intention, we found that they can be assigned to two broad clusters. The first cluster includes the model constructs PBC; self-efficacy; action control; and memory, attention, and decision processes. Self-regulatory processes are at the core of all four constructs. The second cluster includes the constructs of subjective norm and

role and identity. Social influence processes, especially norms, are at the heart of both constructs.

Summary Goal Three: Comparing Patients and Visitors with Healthcare Professionals

The third and final aim of the present study was to examine whether critical determinants for hand hygiene behavior in hospitals differ between healthcare professionals and non-professionals. This was achieved by drawing a qualitative comparison between our survey results and previous research on hand hygiene among healthcare workers. It should be noted that this was not a standardized, quantitative comparison of effect sizes. Some studies used a qualitative method; therefore, comparing effect sizes was not possible.

TPB: The TPB is the most widely used theory to identify determinants for hand hygiene behavior in the literature. Some but not all of the studies of healthcare worker reported all three pre-intentional variables (i.e., attitude, subjective norm, and PBC) as relevant predictors for self-reported hand hygiene compliance (Eiamsitrakoon et al., 2013; McLaws et al., 2012; Whitby et al., 2006), which is in line with our results. In general, PBC consistently emerged as a critical determinant for healthcare workers' hand hygiene behavior (Eiamsitrakoon et al., 2013; Erasmus et al., 2020; McLaws et al., 2012; O'Boyle et al., 2001; Pessoa-Silva et al., 2005; Pittet et al., 2004; Sax, Uckay, et al., 2007; Whitby et al., 2006). Again, this corresponds well with the present study's results, where PBC also emerged as the most influential factor for patients' and visitors' hand hygiene behavior within the TPB.

HAPA: To our knowledge, the only other research project that applied the HAPA to investigate hand hygiene behavior in hospitals was the PSYGIENE project (Lutze et al., 2017; von Lengerke et al., 2015). Unfortunately, the study, which looked at the pre-intentional HAPA variables, did not report correlations with self-reported hand hygiene compliance [46]. The second study, which included the post-intentional HAPA variables, found that compliance among physicians was associated with environmental resources, maintenance self-efficacy, and action control. Self-reported compliance among nurses was only linked to action control. Combined with the PSYGIENE results, we can see action control to be the factor most strongly associated with self-reported hand hygiene behavior or intention across healthcare

professionals and non-professionals. This result is in line with other research (Reyes Fernández et al., 2016) that also identified action control as the primary determinant for hand hygiene behavior outside the healthcare context.

TDF: Three studies identified facilitators and barriers to healthcare workers' hand hygiene behavior, according to TDF (Dyson et al., 2013; Fuller et al., 2014; Smith et al., 2019). Like these studies, we also found memory, attention, and decision processes to be among the most crucial barriers to adequate hand hygiene in hospitals among visitors and patients. Contrary to the studies of healthcare workers, we did not find the knowledge and skills domain to be critical for patients' and visitors' hand hygiene behavior. In one of the healthcare worker-studies (Fuller et al., 2014), the method itself of asking people about their hand hygiene behavior only when they made a mistake seemed to unveil to them that they did not know the appropriate behavior according to the guidelines for the situation. In the other two studies, knowledge and skills was among the less influential determinants (Dyson et al., 2013; Smith et al., 2019). Future research should objectively measure the domain knowledge amongst laypeople to test how important the domain really is. Another consistent barrier to healthcare workers' hand hygiene compliance was the environmental context and resources domain (mainly lack of time and accessibility of products). We did not identify this domain as a relevant barrier for patients' and visitors' hand hygiene. This is plausible since patients and visitors are most likely not constrained by time pressure. Additionally, the availability of hand hygiene products was good in all hospitals in our study. In line with our results, the social/professional role and identity domain was identified as an essential determinant for hand hygiene in two healthcare worker-studies (Dyson et al., 2013; Smith et al., 2019). In the other study (Fuller et al., 2014), participants' verbal explanations for non-compliance with guidelines were recorded and coded. It is plausible that healthcare workers do not link individual cases of non-compliance with their general professional identity at the moment of the event. This last point highlights that the method by which facilitators and barriers to hand hygiene behavior are measured might have an influence on which determinants will surface as being important.

Therefore, the responses patients and visitors give for cleaning or not cleaning their hands in an open-answer format should be compared to the results from the questionnaire findings.

Overall, the critical determinants for healthcare workers' hand hygiene behavior published in the literature are similar to the ones we found for hospital patients and visitors. Some differences between the two target groups might be explained by the method used to measure the model's components and by the studies' designs. However, considering the similarities, we think that successful intervention strategies which improve healthcare workers' hand hygiene behavior might also be useful for targeting patients and visitors.

Limitations

The present study had some limitations. First, all data, including the data that constituted the dependent variable, were self-reported. Previous research has shown that self-reported hand hygiene often only correlates weakly with actually observable behavior and is usually overrated (e.g., Jenner et al., 2006; O'Boyle et al., 2001). To our knowledge, within the hospital environment, the gap between self-reported and observable behavior has been demonstrated only for healthcare workers. It is unclear if patients and visitors are as prone to overreport their hand hygiene behavior in hospitals. But handwashing rates after using the restroom outside hospitals showed that actual rates were significantly lower than self-reported rates (e.g., Nichols, 2014). Nevertheless, using self-reported behavior is a pragmatic and economical way to gather data for large samples in hospitals. Many previous studies have also used self-reported hand hygiene behavior to investigate potential facilitators and barriers (see for instance Table 4). Further research should verify our results using observed behavior as the outcome measure. Second, we employed a cross-sectional study design. This means that no statements about causal effects can be made. One drawback of path diagrams is that they imply a causal direction, which cannot be verified with a cross-sectional dataset. All associations between hand hygiene behavior and model variables are bivariate correlations. But there is longitudinal research on both the TPB and HAPA, indicating the reliability of the described path directions (Lhakhang et al., 2015; Rhodes et al., 2006; Schwarzer et al., 2007; Van De Ven et al., 2007). Third, while the internal consistency of most scales ranged between

excellent and acceptable, some scales did not meet a Cronbach's alpha of at least .70. However, Cronbach's alpha depends on the number of items included in the scale and is often low when the scale consists of only a few items. In this case, using the mean inter-item correlation is more appropriate. In all cases where Cronbach's alpha was below .70, the mean inter-item correlation was within the recommended boundaries of .20 - .50. The CFAs showed that the items for two scales ($HAPA_{Visitors}$: risk perception likelihood and $TDF_{Visitors}$: environmental context) did not load well on one factor, and single items representing the concept the best were included in the model. Measuring perceived risk likelihood with a single item is consistent with some other published research (Lutze et al., 2017; Schwarzer et al., 2011). However, the more complex behavioral domain of environmental context is probably not captured in its entirety with only one item. The bivariate correlation for environmental context did not differ strongly between patients and visitors. Therefore, the results would probably not have fundamentally changed, even when the scale had better psychometric qualities. Nevertheless, several of the HAPA variables and TDF domains were only measured with two items, which is probably not ideal and will only capture a narrow bandwidth of the construct. Further research should be conducted to improve the quality of some of these scales for non-healthcare professionals. Finally, even though we collected data in four different hospitals ranging from a small countryside clinic to a large university hospital, all of them were in Germany and within a 100km radius of each other. Therefore, we cannot tell if the conclusions drawn from our data could be generalized for other countries.

Practical Implications

The present study results have several implications for designing behavior change interventions to improve hospital patients' and visitors' hand hygiene behavior. The results indicate that model constructs related to self-regulatory processes are important determinants for hand hygiene behavior. To reduce the need for self-regulation (i.e., self-monitoring and managing behavior), hospitals could change the environment to nudge people to clean their hands regularly. For instance, placing dispensers at highly visible and accessible locations makes it easier for people to use the dispenser and, therefore, might improve PBC and self-

efficacy. This approach has been shown to increase dispenser usage rates among patients and visitors as well as healthcare workers (Birnbach et al., 2012; Cure et al., 2014; Hobbs et al., 2016; Rashidi et al., 2016). Another method to raise awareness about hand hygiene and prevent forgetting is to install prominent signs and reminders close to hand-rub dispensers (Davis, 2010; Filion et al., 2011; Gaube et al., 2020; King et al., 2016; Rashidi et al., 2016). Technically supported interventions employing attention-grabbing visual and auditory reminders to motivate people to clean their hands have shown promising results for improving hand hygiene behavior in hospitals (Fakhry et al., 2012; Gaube et al., 2018). However, auditory reminders should be used with caution because they might increase noise pollution and alert fatigue. Yet another option to reduce the need for self-regulation from patients and visitors to clean their hands would be to implement a form of compulsory hand hygiene, such as having nurses apply hand rub to patients before meals. This approach has been shown to be an effective way to reduce healthcare-associated infections in a couple of studies (Cheng et al., 2007; Gagne et al., 2010; Pokrywka et al., 2017). However, compulsory hand hygiene programs require additional human resources and might therefore not be feasible for most facilities. Finally, interventions could be designed to improve patients' and visitors' self-regulatory processes by boosting their self-efficacy and PBC. A previous study has shown that participants who created specific hand-washing action plans and were reminded about their ability to comply with these plans and about their past successes increased their handwashing frequency (Lhakhang et al., 2015).

The present study's results also indicate that targeting social influence processes, especially norms, might be a promising approach for a behavior change intervention to improve hand hygiene behavior in hospitals. Patients and visitors reported cleaning their hands more often if they felt it was their responsibility to play an active role in preventing infections and that other people expected them to do it. Therefore, interventions should be designed to convey this idea. Informational materials, signs, and other reminders should include normative messages to highlight the importance of patients' and visitors' roles in infection prevention. Previous studies have shown that employing intervention material that utilizes social influence

processes can increase the hand hygiene rate in healthcare facilities (Gaube et al., 2020; Gaube et al., 2018).

Conclusion

In conclusion, the present study is the first to systematically compare three theoretical models, TPB, HAPA, and TDF, on their usefulness for explaining hospital patients' and visitors' hand hygiene practices. The TDF accounted for the largest share of variance in the self-reported behavior and showed excellent model fit. Two clusters of variables emerged as important determinants for hospital patients' and visitors' hand hygiene behavior: self-regulatory processes and social influence processes. Overall, the determinants for hand hygiene behavior are similar for healthcare professionals (according to the literature) and non-professionals. Therefore, patients and visitors can be included in the infection prevention strategy without substantial changes to the action plans. The results of the present study should help hospital hygiene practitioners to design and evaluate future interventions to improve patients' and visitors' hand hygiene behavior in healthcare facilities. Better hand hygiene practice should help to reduce the rates of healthcare-associated infections and improve patient safety.

Study 2

Utilizing behavioral theories to explain hospital visitors' observed hand hygiene behavior

Susanne Gaube, Wulf Schneider-Brachert, Thomas Holzmann, Peter Fischer, and Eva Lermer

Abstract

Background: Hand hygiene is essential for infection prevention. This study aimed to find a suitable theoretical model and identify critical facilitators and barriers to explain hospital visitors' hand hygiene practice.

Methods: Visitors in four hospitals were observed and asked to give explanations for using or not using the hand rub dispenser. The written explanations of *N* = 838 participants were coded according to three theoretical models: Theory of Planned Behavior (TPB), Health Action Process Approach (HAPA), and Theoretical Domains Framework (TDF).

Results: Self-reported hand hygiene behavior differed from observed behavior, with 15.75% wrongly claiming to have cleaned their hands. Critical facilitators for hand hygiene were *attitude towards the behavior; subjective norm*; *outcome expectancies*; *risk perception*; *planning*; *action control*; *knowledge and skills*; *motivation and goals*; and *social influences*. Key barriers included *perceived behavioral control*; *barriers and resources; memory, attention, and decision processes;* and *environmental context and resources.*

Conclusions: Visitors' self-reported hand hygiene behavior is overreported. Both HAPA and TDF were identified as suitable theoretical models for explaining visitors' hand hygiene practice. Future behavior change interventions should focus on 1) visibility and accessibility of cleaning products; 2) informing laypeople about their role regarding infection prevention; and 3) leveraging social influence processes.

***Keywords*: Hand hygiene, Observed behavior, Behavioral theory, TPB, HAPA, TDF**

Introduction

Hand hygiene is a core element of infection prevention strategies. Cleaning hands with an alcohol-based hand rub is considered the most effective method to avoid cross-transmission of pathogens via touch (Vermeil et al., 2019). Reducing the transmission of bacteria and viruses is especially important in healthcare facilities, which accommodate people who are most vulnerable to infections. Worldwide, hospitals struggle with healthcare-associated infections, which pose a serious threat to the health and safety of patients (Suetens, Latour, Kärki, Ricchizzi, Kinross, Moro, Jans, Hopkins, Hansen, Lyytikäinen, et al., 2018; World Health Organization, 2011). The fact that hand hygiene is an important preventive measure against pathogen transmission and healthcare-associated infection is known by many healthcare workers (e.g., Lutze et al., 2017; Sax, Uckay, et al., 2007) and laypeople (e.g., Srigley et al., 2019). However, the hand hygiene practice of professionals (Erasmus et al., 2010) as well as patients and visitors (Birnbach et al., 2012; Randle et al., 2010) is generally insufficient. Countless interventions to enhance hand hygiene behavior in hospitals have shown that significant improvement is hard to achieve and even more difficult to sustain over time (Gould et al., 2017).

One explanation for the ineffectiveness of many past interventions could be that their design was not grounded in theory (Erasmus et al., 2010). An increasing amount of evidence shows that theory-driven behavior change interventions are more effective in facilitating positive long-term effects (Glanz & Bishop, 2010). Better understanding the facilitators and barriers of hand hygiene behavior in hospitals from a theory-driven perspective could help to design effective interventions. Some efforts in this direction have already been made, with several studies having identified theory-based predictors of hand hygiene behavior among healthcare workers (e.g., Fuller et al., 2014; Lutze et al., 2017; O'Boyle et al., 2001; von Lengerke et al., 2015). However, the facilitators and barriers of patients' and hospital visitors' hand hygiene behavior are not well-researched, despite studies showing that laypeople are a risk factor for the transmission of pathogens that can lead to infections (Birnbach et al., 2015), and improving their hand hygiene behavior reduces healthcare-associated infection rates (Gagne et al., 2010).

Therefore, the main goal of the present study is to investigate determinants for adequate hand hygiene behavior among laypeople in healthcare facilities.

However, studying predictors of human behavior is demanding, and several issues should be taken into consideration. First, the way in which a behavior is measured can have an influence on what kind of facilitators and barriers emerge as being important to predict it (O'Boyle et al., 2001). Many previous studies relied on self-reported hand hygiene behavior rather than directly observed behavior (see Erasmus et al., 2010 for a systematic review). Using self-reports often is the only feasible way to gather data, as observing a large sample in hospitals is extremely labor-intensive and can be felt as obtrusive for the observed people. However, previous research has shown discrepancies between self-reported and observed hand hygiene behavior, with people generally overestimating how often they clean their hands (Jenner et al., 2006; O'Boyle et al., 2001). Therefore, the present study aimed to test whether laypeople's self-reported hand hygiene behavior in hospitals differs from their observed behavior.

Second, choosing a theoretical foundation to explain behavior is challenging. The literature is saturated with different behavioral theories, often with similar or overlapping constructs (Michie et al., 2005). Therefore, in the present study, we tried to identify a suitable theoretical model to explain laypeople's hand hygiene in hospitals from three promising candidates in the relevant literature: the Theory of Planned Behavior (TPB, (Ajzen, 1991)); the Health Action Process Approach (HAPA, (Schwarzer et al., 2011)); and the Theoretical Domains Framework (TDF, (Michie et al., 2005)). All three are well-validated theoretical models that have been used to study hand hygiene behavior before (Fuller et al., 2014; Gaube et al., 2021; O'Boyle et al., 2001; Smith et al., 2019; Srigley et al., 2019; von Lengerke et al., 2015). Definitions of the theoretical models' constructs can be found in Table 1.

Third, the methodology used to measure determinants of hand hygiene behavior might influence which determinants will surface as the most important facilitators and barriers. Previous studies applying the same theoretical model identified slightly dissimilar predictors for hand hygiene behavior, especially when using different methods (qualitative vs. quantitative) to measure the constructs (e.g., Fuller et al., 2014; Smith et al., 2019). It is possible that

respondents are not aware of factors influencing their behavior when providing explanations in an unstructured open-answer format. However, it is also possible that researchers fail to include important components in a structured questionnaire. Therefore, in the present study, we compared coded responses laypeople gave in an open-answer format to those from a previous study that used a structured questionnaire format, to see if facilitators and barriers of hand hygiene behavior that emerge in both answer formats are similar. These findings should help healthcare practitioners to design and evaluate future interventions to improve laypeople's hand hygiene behavior in hospitals.

Table 1.

Theoretical Models and Construct Definitions

Model	Constructs[a]
Theory of Planned Behavior (TPB)	**Attitude towards the behavior**: Beliefs about the positive and negative outcomes of performing a behavior, and the evaluation of these outcomes.
	Subjective norm: Perceptions about normative expectations of significant others regarding a behavior and a person's motivation to comply with these.
	Perceived behavior control: Beliefs about the ease or difficulty involved in performing a behavior.
	Intention: An expression of readiness to perform a behavior.
Health Action Process Approach (HAPA)	**Self-efficacy:** Perceived capability to perform a behavior. (Divided into constructs of task self-efficacy, maintenance self-efficacy, and recovery self-efficacy).
	Outcome expectancies: Assessment of the benefits and disadvantages of performing a behavior.
	Risk perception: Perceived likelihood of experiencing a negative outcome in relation to a behavior, and perceived severity, which is the degree of harm arising from the negative outcome.
	Intention: Explicit decisions to act in a certain way.
	Planning: Specified details about the "when", "where", and "how" to act; and strategies on how to overcome anticipated barriers.
	Barriers and resources: e.g., environmental constraints and social support.
	Action control: Comprises of self-regulatory effort, self-monitoring, and awareness of behavioral standards to adjust a behavior.
Theoretical Domains Framework (TDF)[b]	**Knowledge**: State of being familiar with or aware of something.
	Skills: Ability to do something which is developed through training and practice.
	Social/professional role and identity: Set of beliefs, attitudes, and characteristic behaviors expected of an individual in a social or work setting.
	Beliefs about capabilities: Subjective perceptions of the capability to perform a behavior in a given setting or to attain desired results.
	Beliefs about consequences: Subjective perceptions of the outcomes and consequences of a behavior in a given setting.
	Motivation and goals: Willingness to exert effort in pursuit of a goal or outcome an individual wants to achieve.
	Memory, attention, and decision processes: Ability to retain information, focus on specific aspects of the environment, and choose between alternatives.
	Environmental context and resources: Conditions in a situation or an environment that facilitates or hinders the occurrence of a behavior.
	Social influences (norms): Interpersonal processes that facilitate a change in thoughts, feelings, or behavior.
	Emotions: A complex reaction pattern, by which the individual attempts to deal with a personally significant matter or event.
	Behavioral regulations: Processes aimed toward managing or changing a behavior.

Note. All definitions are based on original publication with regard to the theoretical models and definitions from the American Psychological Associations' Dictionary of Psychology (VandenBos, 2007). [a]TDF constructs are called domains by the model's authors (Michie et al., 2005) but will be referred to as constructs to ensure consistent use of language. [b]The original TDF version (Michie et al., 2005) without the construct "nature of behavior" was employed to make possible the comparison of the coded open-answer responses to those from a previous study that used a structured questionnaire (Gaube et al., 2021). Definitions and results for the revised TDF version (Cane et al., 2012) can be found in the supplementary materials.

Method

Design

A cross-sectional study was employed to investigate visitors' explanations for using or not using hand rub dispensers. The study was approved by the management of the involved hospitals. All participants gave oral consent to complete a questionnaire. The responsible Research Ethics Committee does not require a full ethical review of psychology studies with low risk.

Data Collection

The study took place at three German hospitals, ranging in size from a small countryside clinic to a large university hospital. Convenience sampling was used to select one hospital from each of the three available care levels in the state (primary to tertiary care). Data were collected at the hospital's lobbies, where a team of trained research assistants observed whether people entering the building used the hand rub dispensers. Previous studies have also used hospital lobbies to observe visitors' hand hygiene behavior (Birnbach et al., 2012; Gaube et al., 2020), because visitors should sanitize their hands before patient contact, and the lobby's dispenser provides the first possibility for them to do so. The observers were located at a distance to the sole available dispenser in each lobby, allowing them to monitor the behavior unobtrusively. People who visually appeared to be visitors (e.g., not attired in scrubs, hospital gowns, loungewear or pajamas) were approached several meters behind the dispenser by the same research assistant who observed their behavior; the research assistant then asked the person whether they came as a visitor. Already admitted patients were excluded as they have little reason to use the dispenser at the lobby. Newly arriving patients were also omitted because

straining them with a questionnaire unrelated to their medical condition seemed inappropriate. Individuals who confirmed their status as visitors and to having not partaken in this study before were asked to participate. Visitors who consented to take part in the study received a questionnaire which, unbeknownst to them, was marked with a symbol indicating whether they had used the dispenser or not. Participants were not informed about the meaning of the symbol to avoid biasing their self-report. The visitors were asked to fill out the questionnaire on the spot in the lobby. Data were collected from December 2017 to November 2019.

Materials

The survey, estimated to take less than 15 minutes to complete, included information regarding the study's purpose and instructions. This was followed by questions about demographics, previous experiences with healthcare-associated infections, and whether the patient they visited had a heightened infection risk. Participants were asked if they had sanitized their hands at the lobby's sole hand rub dispenser right after entering the hospital and to explain their reasons for their behavior in an open-answer format (qualitative approach). Finally, participants were presented with questionnaire items to measure the constructs of the three theoretical models TPB, HAPA, and TDF (quantitative approach). The results of the quantitative approach are reported in a separate paper (Gaube et al., 2021).

Participants

Overall, 1040 hospital visitors returned the questionnaire to the observers or left it at the reception. Of these, 838 (age ranged 18 to 91 years; M = 49.02, SD = 16.77; 59.1% female) provided an explanation for using or not using the hand rub dispenser in the hospital lobby and were included for further analysis (a drop-out analysis can be found in the supplementary materials). Most participants (73.5%) had no previous experiences with healthcare-associated infections. When asked whether the patient they visited had a heightened infection risk, 53.7% said no, 28.3% affirmed the question, while 14.8% were not sure. A detailed sample description stratified by the hospitals in which the data was collected can be found in the supplementary materials (Table S2).

Data Analysis

The goal was to identify facilitators and barriers of visitors' hand hygiene behavior from their immediate explanations for using or not using the hand rub dispenser. Therefore, the research team developed three sets of codebooks—one for each theoretical model—to classify responses into the constructs[1]. Each construct was coded as 1 = *mentioned* or 0 = *not mentioned* in the explanation. A similar approach to a theory-guided coding of qualitative data has been used in previous studies (Fuller et al., 2014; Srigley et al., 2019). The open-answer explanations were coded according to these rulebooks independently by the same three trained raters. Every visitor's explanation for using or not using the hand rub dispenser was coded separately for each theoretical model. Coding every response three times allowed for drawing direct comparisons between the three theoretical models. The explanations were coded to more than one construct whenever it was deemed necessary (e.g., when the response included more than one reason). The construct *intention* (relevant for TPB and HAPA) was not coded, as it was considered unlikely that a person would express an explicit intention to use the dispenser as a reason for doing so. A review of all explanations confirmed this assumption. The inter-rater reliability was calculated using the intraclass correlation coefficient (ICC), which is a commonly used index in interrater reliability analyses between two or more raters. All ICC values were between 0.79 and 1.00, indicating good to excellent inter-rater reliability. The remaining disagreements were discussed until a consensus was reached. The McNemar test, applicable for testing differences on a dichotomous dependent variable in a paired sample, was used to determine whether visitors' self-reported hand hygiene behavior (yes/no) differed from the observed behavior (yes/no). Binomial logistic regressions, typically deployed for regression analyses with dichotomous dependent variables, were used to test which constructs are relevant for predicting dispenser usage (yes/no). All statistical analyses were run in R version 3.6.3. The study's data and R-script will be made available online upon publication: https://osf.io/5vq94/

[1] The three codebooks are in German language but can be made available in English upon request.

Results

Hand Hygiene Behavior

According to the observation, 223 (26.6%) participants used the hand rub dispenser at the hospital, while 615 (73.4%) did not. When asked if they had sanitized their hands at the lobby's hand rub dispenser right after entering the hospital, 355 (42.4%) visitors affirmed that they had, while 483 (57.6%) said they had not. Accordingly, 15.8% of the visitors claimed to have cleaned their hands at the hand rub dispenser in the lobby, while the observation data shows that they did not. Visitors' self-reported hand hygiene behavior in the hospital lobby differed significantly from the observed behavior (χ^2 = 130.01, p < .001). Participants with a discrepancy between observed and self-reported behavior were removed from further analysis, leaving a total of N = 706 visitors.

We tested if age, gender, previous experiences with healthcare-associated infections, and the visited patient's infection risk could predict hand rub dispenser usage in the hospital lobby. All variables were included in a logistic regression with observed hand hygiene as the criterion. Only previous experience with healthcare-associated infections emerged as a significant predictor (p < .001). People who reported previous experience were more likely to clean their hands (see Table 2).

Table 2

Logistic Regression Results Using Observed Hand Hygiene Behavior as the Criterion

Predictor						95% CI for OR	
	b	*SE*	*z*	*p*	*OR*	LL	UL
Constant	-1.19	0.29	-4.05	<.001	0.31	0.17	0.54
Age	0.00	0.01	0.09	.930	1.00	0.99	1.01
Gender (female)	0.19	0.18	1.08	.280	1.21	0.86	1.72
Experience (yes)	0.67	0.19	3.56	<.001	1.95	1.35	2.81
Infection risk							
Heightened risk (yes)	0.22	0.19	1.15	.252	1.24	0.85	1.81
Unclear risk (don't know)	0.15	0.25	0.61	.540	1.17	0.71	1.89

Note. b = unstandardized coefficient, *SE* = standard error; *z* = b/*SE, p* = probability value, *OR* = odds ratio, LL = lower limit, UP = upper limit; $-2LL$ = 803.25, Model $\chi^2(5)$ = 16.28, p = .006, AIC = 815.25, BIC = 842.17; R^2 = 0.02 (Hosmer–Lemeshow), 0.02 (Cox–Snell), 0.03 (Nagelkerke).

Theoretical Models Predicting Hand Hygiene Behavior

Table 3 shows the numbers of visitors' explanations coded to each theoretical model, along with examples. If an explanation did not fit to one of the theoretical models' constructs, it was coded as "other". Fewer explanations had to be coded as "other" for theoretical models that had more constructs (TPB: 3 constructs and 50.5% of explanations coded to "other;" HAPA: 6 constructs and 26.5% "other;" and TDF: 11 constructs and 16.5% "other). This means that more detailed theoretical models allowed more explanations to be allocated to existing constructs.

The constructs contained within the theoretical models can be considered as either facilitators or barriers for hand hygiene behavior. A construct is regarded as a facilitator when explanations coded into it were mainly given by dispenser users but not by non-users. When the opposite is true, the construct is regarded as a barrier. Facilitators that accounted for more than 10% of explanations were *attitude towards the behavior* (TPB), *outcome expectancies* (HAPA), *risk perception* (HAPA)*, knowledge and skills* (TDF), *beliefs about consequences* (TDF), and *motivation and goals* (TDF). Barriers that accounted for more than 10% of explanations were *perceived behavioral control* (TPB); *barriers and resources* (HAPA); *memory, attention, and decision processes* (TDF); and *environmental context and resources* (TDF).

To test which constructs are relevant for predicting dispenser usage, three logistic regressions—one for each theoretical model—were calculated. Only constructs that were mentioned at least once by both dispenser users and non-users were included as predictors. Table 4 shows the results of the three regressions. Including the constructs as predictors for observed hand hygiene behavior improved the fit of all three regression models compared to the baseline model with only the constant ($p < .001$). The Hosmer-Lemeshow goodness of fit tests, used to assess model calibration, showed no evidence for poor fit (all $p > .050$). Model discrimination assessed through area under the ROC curve is excellent ($ROC_{TPB} = 0.87$, $ROC_{HAPA} = 0.92$, $ROC_{TDF} = 0.92$). The calculated model parameters suggest that the HAPA and the TDF both fit the data very well (see notes Table 4). Assessing the contributions of the individual predictors shows which constructs are most important for explaining the behavior. All TPB and HAPA constructs included in the regressions made a significant contribution to the

prediction of observed hand hygiene behavior. In the TDF regression model, the constructs *knowledge and skills*; *motivation and goals*; *memory, attention, and decision processes*; *environmental context and resources;* and *social influences* emerged as significant predictors.

Table 3

Frequency (n and %) of Written Explanations for Using/Not Using the Hand Rub Dispenser Coded to Constructs of the Three Theoretical Models With Examples

Model	Construct	Dispenser users			Dispenser non-users		
		n	%	Example	*n*	%	Example
Theory of Planned Behavior (TPB)	Attitude towards the behavior	158	20.8%	"I think it is right and I feel protected from bacteria [ ]"	40	5.3%	"I don't like it; I'm afraid for my good micro-organisms"
	Subjective norm	17	2.2%	"It is our duty and out of consideration for others"	1	0.1%	"I just followed the flow of people"
	Perceived behavioral control	8	1.1%	"Placed directly at the entrance, easy to reach, [ ]"	152	20.0%	"I could not find a hand rub dispenser"
	Other	62	8.2%	"Habit"	321	42.3%	"Totally forgot"
	Total	245	32.3%		514	67.7%	
Health Action Process Approach (HAPA)	Self-efficacy	2	0.2%	"[ ] I can make a contribution to minimize infections"	0	0.0%	-
	Outcome expectancies	113	11.8%	"For my own safety and protection for others"	7	0.7%	"The skin burns from hand rub"
	Risk perception	129	13.5%	"Bacteria are everywhere, and I want to reduce the risk"	5	0.5%	"The danger only begins inside the hospital"
	Planning	32	3.3%	"Always use the dispenser when entering a hospital"	86	9.0%	"I always clean my hands in the room"
	Barriers and resources	8	0.8%	"It was recommended to me"	166	17.4%	"I did not see a dispenser; I did not see a sign"
	Action control	79	8.3%	"I know about the subject"	76	7.9%	"I didn't know about it"
	Other	42	4.4%	"It smells so good."	211	22.1%	"Don't know, [ ]"
	Total	405	42.4%		551	57.6%	

Model	Construct	Dispenser users			Dispenser non-users		
		n	%	Example	*n*	%	Example
Theoretical Domains Framework (TDF)	Knowledge and skills	154	14.62	“Prevention of nosocomial infections”	31	2.94	“I was not aware of the problem”
	Social/professional role and identity	15	1.42	“It should be taken for granted for all visitors [ ]”	0	0.00	-
	Beliefs about capabilities	2	0.19	“[ ] I can make a contribution to minimize infections”	4	0.38	“I had my hands full, so I could use the dispenser”
	Beliefs about consequences	116	11.02	“it [ ] kills off bacteria”	25	2.37	“The skin burns from hand rub”
	Motivation and goals	106	10.07	“I want to protect myself from bacteria and viruses”	3	0.28	“Not in the mood”
	Memory, attention, and decision processes	1	0.09	“Didn’t really think about it [ ]”	163	15.48	“Totally forgot”
	Environmental context and resources	25	2.37	“Placed directly at the entrance, easy to reach”	212	20.13	“I did not see a dispenser; I did not see a sign”
	Social influences	5	0.47	“It is our duty and out of consideration for others”	3	0.28	“I just followed the flow of people”
	Emotions	1	0.09	“Fear of infections”	4	0.38	“I don’t like it; I’m afraid for my good micro-organisms”
	Behavioral regulations	2	0.19	“Mandatory”	7	0.66	“It’s not specifically pointed out”
	Other	55	5.22	“Habit”	119	11.30	“I’ll do it at the ward”
	Total	482	45.77		571	54.23	

Note. Knowledge and skills were combined into one construct.

Table 4

Logistic Regression Results Using Observed Hand Hygiene Behavior as the Criterion

Model	Predictor	*b*	*SE*	*z*	*p*	*OR*	95% CI for OR	
							LL	UL
Theory of Planned Behavior (TPB)[a]	Constant	-1.79	0.15	-11.73	<.001	0.17	0.12	0.22
	Attitude towards the behavior	3.18	0.23	13.66	<.001	24.08	15.41	38.45
	Subjective norm	4.44	1.07	4.14	<.001	84.99	15.47	1603.07
	Perceived behavioral control	-1.60	0.42	-3.82	<.001	0.20	0.08	0.43
Health Action Process Approach (HAPA)[b]	Constant	-2.57	0.24	-10.74	<.001	0.08	0.05	0.12
	Outcome expectancies	2.86	0.51	5.57	<.001	17.45	6.61	50.59
	Risk perception	4.38	0.52	8.35	<.001	79.70	30.89	249.88
	Planning	0.78	0.30	2.61	.009	2.18	1.21	3.91
	Barriers and resources	-1.19	0.47	-2.54	.011	0.31	0.11	0.72
	Action control	2.13	0.28	7.76	<.001	8.45	4.98	14.68
Theoretical Domains Framework (TDF)[c]	Constant	-0.72	0.18	-4.12	<.001	0.49	0.34	0.68
	Knowledge and skills	1.87	0.36	5.16	<.001	6.47	3.25	13.53
	Beliefs about capabilities	-0.64	1.11	-0.58	.564	0.53	0.03	3.62
	Beliefs about consequences	-0.74	0.43	-1.73	.083	0.48	0.20	1.08
	Motivation and goals	4.04	0.84	4.81	<.001	57.04	13.79	423.43
	Memory, attention, and decision processes	-4.74	1.09	-4.34	<.001	0.01	0.00	0.05
	Environmental context and resources	-1.63	0.29	-5.67	<.001	0.20	0.11	0.34
	Social influences	2.11	1.08	1.97	.049	8.28	1.08	86.45
	Emotions	-1.84	1.19	-1.55	.122	0.16	0.01	1.27
	Behavioural regulations	-1.55	1.16	-1.33	.184	0.21	0.02	1.86

Note. b = unstandardized coefficient, *SE* = standard error; *z* = b/*SE, p* = probability value, *OR* = odds ratio, LL = lower limit, UP = upper limit;

[a] $-2LL$ = 525.39, Model $\chi^2(3) = 355.29$, $p < .001$, AIC = 533.39, BIC = 551.63; R^2 = 0.40 (Hosmer–Lemeshow), 0.40 (Cox–Snell), 0.55 (Nagelkerke).

[b] $-2LL$ = 419.63, Model $\chi^2(5) = 461.06$, p < .001, AIC = 431.63, BIC = 458.98; R^2 = 0.52 (Hosmer–Lemeshow), 0.48 (Cox–Snell), 0.67 (Nagelkerke).

[c] $-2LL$ = 428.76, Model $\chi^2(9) = 451.92$, p < .001 AIC = 448.76, BIC = 494.36; R^2 = 0.51 (Hosmer–Lemeshow), 0.47 (Cox–Snell), 0.66 (Nagelkerke).

Discussion

The data shows that hospital visitors' self-reported hand hygiene behavior differed significantly from their observed behavior. In total, 15.8% of visitors claimed to have sanitized their hands in the lobby while the observation showed that they did not. This finding is consistent with previous research showing that self-reported hand hygiene is usually overreported (Jenner et al., 2006; O'Boyle et al., 2001). Hand hygiene is morally loaded, which makes it prone to socially desirable responding. Therefore, relying on self-reporting to measure visitors' hand hygiene behavior is not ideal. Still, the majority of visitors reported their behavior correctly. Therefore, if cheap, unobtrusive, and widely applicable methods of accurately measuring hand hygiene behavior are not available, relying on self-reported data may be an acceptable alternative for research in this area.

All three theoretical models (TPB, HAPA, and TDF) proved useful for examining visitors' hand hygiene behavior. Visitors who cleaned their hands provided slightly more detailed explanations for their actions. Dispenser users predominantly gave explanations highlighting their awareness of being a risk factor for the transmission of dangerous pathogens and their effort to avoid negative consequences. Non-users mainly blamed the hospital environment or the situational context for not being able to clean their hands. Most explanations from non-users indicate that they knew that hand hygiene was appropriate but searched for reasons why they did not use the dispenser. People often ascribe reasons for their behavior in a manner that helps fulfill their desire for a positive self-image. This is known as *self-serving attributional bias*, which is the tendency to attribute positive events to ourselves and our own actions while attributing negative events to others and situational factors (Mezulis

et al., 2004). It is possible that many visitors were subject to this attribution bias. Very few explanations were coded to the following constructs: *subjective norm*, *self-efficacy*, *social/professional role and identity*, *beliefs about capabilities*, *social influence*, *emotions*, or *behavioral regulations*. The respondents seemed to be unaware of or downplay the influence of social processes and emotions, which is consistent with other research and might reflect people's desire to provide rational explanations for their decisions (Cialdini, 2016). *Perceived capability/self-efficacy* to perform hand hygiene was a largely irrelevant construct for the visitors, most likely because using a hand rub dispenser is such a simple task.

Considering the suitability of the three logistic regressions modelled according to the three theoretical models to predict dispenser usage, both HAPA and TDF fit the data well and better than the TPB. It is noteworthy that the HAPA's model fit was on par with TDF for two reasons. First, HAPA is more parsimonious in using constructs to explain behavior than TDF. Second, in previous work drawing from the same sample that also utilized a questionnaire for measuring the constructs to predict self-reported hand hygiene behavior (Gaube et al., 2021), HAPA had a worse model fit and predicted less variance than TDF. The fact that TDF emerged as a suitable model is consistent with these previous results (Gaube et al., 2021). Additionally, TDF allowed the most explanations to be allocated to existing constructs, showing some merit of a more comprehensive framework approach for understanding behavior. Having coinciding evidence from both a qualitative (i.e., coded open-answer format) and a quantitative (i.e., structured questionnaire) approach, TDF appears to be a solid theoretical model to explain and predict the facilitators and barriers of laypeople's hand hygiene practice in hospitals. However, it should be noted that TDF is theoretical framework and not a theory. Unlike TPB and HAPA, it does not propose any testable causal processes linking the theoretical constructs. Nevertheless, it has been extensively used for the implementation of evidence-based practice.

We now turn to discuss which components are most relevant to predict visitors' hand hygiene behavior for the three theoretical models separately:

- **TPB**: All three TPB-constructs significantly predicted observed dispenser usage among visitors. Visitors giving explanations coded into the constructs *attitude towards the behavior* and *subjective norms* were more likely to use the hand rub dispenser. In contrast, participants who provided explanations coded into the construct *perceived behavioral control* were less likely to use the dispenser. This is consistent with the findings of a previous study using a quantitative approach (structured questionnaire format), where all three constructs significantly correlated with either *intention* to clean hands or with self-reported hand hygiene behavior (Gaube et al., 2021).
- **HAPA:** The five HAPA-constructs included in the regression model also significantly predicted observed hand hygiene behavior. Hospital visitors who gave explanations coded into the constructs of *outcome expectancies*, *risk perception*, *planning,* and *action control* were more likely to perform hand hygiene in the lobbies. Participants who gave explanations coded into the construct *barriers and resources* were less likely to use the hand rub dispenser. Since no explanation from non-users was coded into the construct of *self-efficacy*, it was not included in the logistic regression. This made comparing the qualitative and quantitative HAPA results harder. Nevertheless, in both analyses, *outcome expectancies*, *risk perception*, and *action control* surfaced as important facilitators for hand hygiene behavior or *intention* as a mediator (Gaube et al., 2021).
- **TDF:** Not all TDF-constructs emerged as significant predictors for visitors' dispenser usage. Observed hand hygiene was positively associated with visitors' explanations fitting into the constructs *knowledge and skills*, *motivation and goals*, and *social influences.* Visitors who wrote explanations related to *memory, attention, and decision processes* and *environmental context and resources* were less likely to use the dispenser. As with HAPA, a direct comparison of results from the qualitative and the quantitative approach is not possible, since *social/professional role and identity* was not included in the logistic regression. Still, *knowledge and skills*, *social influences*, and *memory, attention, and decision processes* emerged as important constructs for visitors' hand hygiene behavior in

both analyses (Gaube et al., 2021). These findings are also consistent with another recent study on patients' hand hygiene behavior (Srigley et al., 2019).

Considering these results, three implications for future behavior change interventions can be deduced: 1) Hand rub dispensers need to be placed at highly visible and easily accessible locations to prevent forgetting and facilitate their usage. 2) Interventions should be designed to raise awareness that laypeople are a risk factor for the transmission of dangerous pathogens and explain that adequate hand hygiene can reduce this risk. 3) Interventions should utilize social influence processes. For instance, informational materials and reminders could contain normative messages highlighting that hand hygiene is the norm.

From a methodological perspective, results from using coded open-answer explanations (qualitative approach) and structured questionnaire scales (qualitative approach) as predictors for visitors' hand hygiene behavior are not identical but reasonably consistent. This consistency indicates that both approaches seem to be reliable methods to investigate facilitators and barriers of laypeople's hand hygiene behavior.

Limitations

This study had some limitations. First, the original TDF-constructs have overlying components. For instance, the constructs *social/professional role and identity* and *social influences* both contain the components of *social norms* as well as *identity*. This makes a distinct coding of visitors' explanations into the constructs challenging. In cases with overlapping components, we coded the explanations to both constructs, which increases the risk for multicollinearity. However, we found no evidence for critical multicollinearity between the predictors (all *VIF*s between 1.01 and 1.71). Second, the explanations for using or not using the dispenser tended to be brief, not very detailed, and sometimes slightly ambiguous, which made the coding process more challenging. However, the inter-rater reliability was very good, indicating that the raters coded the explanations consistently. Third, the study was conducted prior to the COVID-19 pandemic. It might be assumed that, due to the pandemic, hospital visitors are currently more aware of the importance of hand hygiene. More research is needed to validate the relevance of the identified facilitators and barriers after the crisis.

Fourth, the visitors' explanations used for coding the predictors were given after the behavior occurred and might be a post-hoc rationalization for their action. This is very hard to avoid even when predictors are measured before the occurrence of the outcome, since people often consider their past behavior when making judgements and decisions about a future action. Finally, several non-users claimed to clean their hands later on at the ward or the patient room. Since the researchers did not follow visitors through the hospital, it cannot be determined if they actually did so. Future research should be conducted to observe visitors' hand hygiene behavior throughout the hospital.

Conclusion

The aim of the present study was to expand the understanding of hospital visitors' hand hygiene behavior. The analysis showed that visitors overreported their hand-rub dispenser usage in comparison to direct observation, which provides further evidence that relying solely on self-reported data is insufficient when studying hand hygiene behavior. This was the first study to use visitors' open-response explanations coded according to three theoretical models as predictors for their observed dispenser usage. While all theoretical models helped to explain visitors' behavior, HAPA and TDF emerged as more useful than TPB. The identified facilitators and barriers of hand hygiene behavior lead to three important implications for future interventions: 1) placing dispensers in highly visible and easily accessible locations; 2) informing laypeople about their role in the infection prevention strategy; and 3) leveraging social influence processes. These implications should help practitioners design and evaluate interventions to improve visitors' hand hygiene behavior. Better hand hygiene practice can prevent healthcare-associated infections and improve safety for everyone in healthcare facilities.

Study 3

The effect of persuasive messages on hospital visitors' hand hygiene behavior

Susanne Gaube, Peter Fischer, Verena Windl, and Eva Lermer

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Abstract

Objective: Hospital visitors pose a risk for transmitting pathogens that can cause healthcare-associated infections. The present study aimed to test an evidence-based intervention to improve visitors' hand hygiene behavior through persuasive messages. **Methods:** For the 14-week-long field experiment, seven signs were designed according to the principles of persuasion proposed by Cialdini: *reciprocity*, *consistency*, *social-proof*, *unity*, *liking*, *authority*, and *scarcity*. Each sign was displayed on a screen for one week directly above the hand-rub dispenser in a hospital lobby. Between each posting, the screen was blank for one week. **Results:** An electronic monitoring system counted 246,098 people entering and leaving the hospital's lobby and 17,308 dispenser usages. The signs based on the *authority* and the *social-proof* principles significantly increased the hand-rub dispenser usage rate in comparison to the average baseline usage rate. **Conclusions:** These results indicate that simple and cost-efficient interventions can initiate expedient behavior change in hospitals. However, the findings also highlight the importance of careful planning and rigorous pre-testing of material for an intervention to be effective. Theoretical and practical implications of these findings are discussed.

Introduction

Healthcare-associated infections pose a threat to patient safety. Infections impair the patient's health, can lead to long-term physical and mental problems, and, in the worst case, result in the patient's death. The World Health Organisation (WHO) estimates that hundreds of millions of patients are affected by healthcare-associated infections annually (World Health Organization, 2011). According to the WHO, up to 7% of patients in industrialized countries and up to 10% of patients in developing countries will acquire at least one healthcare-associated infection (World Health Organization, 2016). In Germany, where the present study was conducted, the prevalence of patients with healthcare-associated infections was 4.6% across 218 hospitals in 2016 (Behnke et al., 2017). In healthcare facilities, hygienic hand disinfection is one of the main elements of infection prevention. Appropriate hand hygiene inhibits the transmission of pathogens and reduces the risk of patients acquiring an infection (Allegranzi & Pittet, 2009; Pittet et al., 2000; World Health Organization, 2009).

Healthcare workers' hand hygiene behavior has been a focus of behavior change researchers for years. Contaminated healthcare workers' hands are the most common vehicle for patient-to-patient pathogen transmission (Allegranzi & Pittet, 2009). However, studies have shown that hospital visitors carry dangerous pathogens on their hands as well (e.g., Birnbach et al., 2015). These findings suggest that hospital visitors might be a relevant but largely neglected vector for pathogen transmission. Visitors of a healthcare facility should clean their hands at least before and after contact with a patient (Munoz-Price et al., 2015). Accordingly, the German Commission for Hospital Hygiene and Infection Prevention recommended including visitors in hospitals' hand hygiene campaigns (Kommission für Krankenhaushygiene und Infektionsprävention, 2016).

Little is known about how often and in what situations visitors clean their hands in hospitals. Visitors' hand hygiene rates vary among published reports. Several studies looked at how frequently visitors used hand-rub dispensers in hospital lobbies. Pittz (2009) observed 71 facilities and found that less than one percent of visitors used the dispenser. Very low usage rates were also found in three other studies (Birnbach et al., 2012; Vaidotas et al., 2015). The

location of the hand-rub dispenser seems to be one important factor for increasing usage by visitors. Studies found considerable higher usage rates when the dispenser was free-standing and centrally located (Birnbach et al., 2012; Hobbs et al., 2016). Hobbs et al. (2016) also identified three visitor characteristics that were associated with dispenser usage in the hospital lobby: younger visitors, groups of visitors and visitors in the afternoon were more likely to clean their hands at the dispenser than older visitors, individual visitors and morning visitors, respectively. Still, all studies show that there is extensive room for improvement that might help to enhance patient safety.

Using signs to convey messages about health and safety is a popular intervention strategy to remind healthcare workers and laypeople to clean their hands (Jenner, Jones, Fletcher, Miller, & Scott, 2005) and also recommended by the Kommission für Krankenhaushygiene und Infektionsprävention (2016). However, the reported effectiveness of sign-based interventions is mixed. For instance, Grant and Hofmann (2011) found that signs emphasizing patient safety improved professionals' hand hygiene practice, while signs addressing personal safety had no effect. Signs stressing the fact that hand hygiene saves lives did not significantly improve hand hygiene behavior (Birnbach et al., 2017), nor did a sign claiming that hand sanitation was mandatory for all visitors (Birnbach et al., 2012; Birnbach et al., 2017).

In general, purely informative messages explaining risk also often fail to provoke change. The effectiveness of behavior change campaigns depends not only on the message's content but also on its tone (Joffe, 2008). Health campaigns often use threatening materials like shocking images or disgust-evoking pictures (Gaube et al., 2019; Joffe, 2008). However, it is important for patients' wellness and health outcomes to feel safe in hospitals (Mollon, 2014) and trust in healthcare professionals (Birkhäuer et al., 2017). Targeting emotions like *fear* and *disgust* might evoke unintended negative feelings towards the hospital environment and could result in defensive responses (Leshner et al., 2009). Therefore, we abstained from using threatening material in the present study.

The intervention should be grounded in theory, as evidence-based interventions are considered to be more effective (Abraham et al., 2009; Albarracín et al., 2001). Therefore, the nature of the target behavior was analyzed first. For many people, cleaning the hands is an automatized behavior that does not involve much deliberate thinking (Aunger et al., 2010). Consequently, relying on cognitively demanding messages explaining the risk of pathogen transmission might be suboptimal. Persuading hospital visitors to clean their hands by using messages that trigger an automatic response might be a promising approach. (Cialdini, 2007, 2016) summarized seven fundamental principles of persuasion through which people are often involuntarily influenced:

(1) *Reciprocity*: People feel obliged to repay acts of generosity such as favors.
(2) *Consistency*: People have an internal desire to be and be seen as consistent in attitudes and actions and behave consistently with existing commitments.
(3) *Unity*: People are more easily influenced by people they perceive as part of their in-group.
(4) *Social-proof*: People look to other peoples' opinions and behaviors to decide what is appropriate.
(5) *Liking*: People are more easily persuaded by someone they like or perceive as likable.
(6) *Authority*: People often obey authorities and defer to experts.
(7) *Scarcity*: People are motivated to avoid losses, and therefore tend to perceive scarce resources as being more valuable then readily available resources.

The effectiveness of these principles in nudging people has been confirmed for a variety of behaviors like restaurant tipping (Strohmetz et al., 2002), environmental conservation (Goldstein et al., 2008), helping behavior (Bushman, 1988), and many more (see Cialdini, 2016). Cialdini describes the principles as triggering automatic behavioral reactions through processes that are often subtle and indirect (Cialdini, 2007). Targeting influence processes that prompt automatic behavioral reactions has been shown to be effective in persuading people to clean their hands. For example, (Birnbach et al., 2013; King et al., 2016) used olfactoric priming with a fresh scent to help improve compliance among hospital workers. Two other studies made social norms salient by displaying text-based messages at highway service

station restrooms (Judah et al., 2009) and emojis in patient rooms (Gaube et al., 2018) which helped to increase hand hygiene rates. The present study's goal was to see if signs based on the seven principles of persuasion help to improve visitors' hand hygiene behavior at a hospitals' lobby. To the best of our knowledge, it has never been systematically tested if the principles facilitate behavior change in this specific context, nor has the effectiveness of each of the seven principles been directly compared with each other. Therefore, we did not formulate an a-priori hypothesis on which of the principles might be most persuasive in motivating hospital visitors to clean their hands.

Method

We designed seven signs according to the principles of persuasion and compared their effect on visitors' hand hygiene behavior to the baseline situation in which no sign was present at a lobby in a German hospital. The reason for observing the behavior at the hospital's entrance was twofold: First, several previous studies have used that location to observe visitors' hand hygiene behavior. Therefore, the results of the present study can be compared with previous research. Second, at the chosen facility, all visitors must enter through the main lobby, which makes it easy to observe the hand hygiene behavior of a large volume of people. The study took place between August and November 2018 and lasted 14 weeks in total. Collecting data over this extended period allowed us to observe 246,098 people entering and leaving the hospital's lobby. This sample even exceeds a comparable previous study in which text-based messages were displayed at highway service station restrooms to improve handwashing behavior (Judah et al., 2009). The hospital was chosen because it is an acute care hospital with a variety of medical specialties and diverse patient clientele, which should translate into its visitors being a good representation of the general public in that area.

Material Development

All signs consisted of a photo on the left that filled about two-thirds of the space and a message in German on the right in capital letters. Additionally, every sign included the phrase "Please disinfect your hands!" at the lower-right corner to make sure the desired behavior was

made clear to every visitor. An expert team of five social psychologists familiar with the seven principles of persuasion conducted a workshop to design messages that put each principle into practice to prompt hospital visitors to clean their hands. In total, 34 messages (four for the authority principle and five for the other six principles) were finally agreed on to use for a subsequent online pre-test. Additionally, the workgroup developed ideas for pictures that could convey the messages optimally. For each principle, two picture ideas were chosen during the workshop. It was decided to pair text with images because using pictures is an effective way to convey a message (Joffe, 2008). According to Joffe (2008), visuals have three advantages over purely text-based messages: (1) pictures are easier to remember; (2) visuals are considered a credible source of information, and (3) visual material conveys emotions. To increase their authenticity, the 14 (two for each principle) picture ideas were captured in a photoshoot at the hospital in which the study took place. The staff members were employees at the hospital at the time of the study. The visitors and the patient are local residents and familiar with the hospital. The group of people was chosen in regard to age, gender, and ethnicity to be a rough representation of the district's population and the hospital's usual visitor demographic.

Material Pre-Test

Subsequently, an online survey was conducted to identify the best message and picture for each principle. In the survey (N = 35), participants, which were recruited through personal address, first received a short explanation for each principle of persuasion. Each explanation was followed by four or five messages developed by our expert team to be in accordance with the respective principle. Participants had to rate how well each message expressed the principle on a seven-point Likert scale, from 1 (*completely inconsistent*) to 7 (*completely consistent*). After rating the messages, the participants saw four pictures, two that were designed by our expert team to fit the principle and two randomly selected distractors from the other principles. Participants were asked to rate how well the pictures reflected the messages on a seven-point Likert scale, from 1 (*completely inconsistent*) to 7 (*completely consistent*). Finally, for each principle, the message with the highest rating and the picture

reflecting the messages the best were matched. Table 1 contains the pre-test ratings of the seven messages and pictures with the highest ratings selected for the field experiment. A professional graphic designer finalized all signs. Images, messages with translations, and the pre-test rating results of all seven signs tested in the field experiment can be found in the online supplement.

Table 1

Pre-Test Ratings of the Messages and Pictures Selected for the Signs

	Message Rating		Image Rating	
Principle	*M*	*SD*	*M*	*SD*
Reciprocity	4.7	1.5	5.8	1.4
Consistency	5.3	1.2	4.3	1.9
Unity	5.3	1.7	5.7	1.3
Social-proof	5.4	1.1	6.0	1.0
Liking	5.9	1.1	5.7	1.3
Authority	5.7	0.9	5.4	1.4
Scarcity	5.7	1.3	4.9	1.6

Note. Item for the message rating: "How consistent is the message with the proposed principle?"; Item for the image rating: "How consistent is the picture with the messages above?" Both were rated on a seven-point Likert scale from 1 = *completely inconsistent* to 7 = *completely consistent.*

To aid discoverability and facilitate the integration of the results with other interventions of health-related behavior studies, the behavior change techniques used in the seven signs are coded according to the Behaviour Change Technique Taxonomy v1 (BCT-T-v1; Michie et al., 2013). All signs are *prompts/cues* [7.1] displayed to facilitate hand hygiene behavior. Placing a TV screen above the hand-rub dispenser can be coded as *adding objects to the environment* [12.5]. The individual signs can be coded with behavior change techniques as follows. Reciprocity: *information about others' approval* [6.3] and *credible source* [9.1]. Consistency: *commitment* [1.9] and *information about health consequences* [5.1]. Unity: *information about health consequences* [5.1], *demonstration of the behavior* [6.1], *social comparison* [6.2], and *information about others' approval* [6.3]. Social-proof: *demonstration of the behavior* [6.1], *social comparison* [6.2], and *information about others' approval* [6.3]. Liking: *information about health consequences* [5.1], *information about others' approval* [6.3], *credible*

source [9.1]. Authority: *information about others' approval* [6.3] and *credible source* [9.1]. Scarcity: *information about health consequences* [5.1] and *salience of consequences* [5.2].

Study Design

From previous observations, it was known that visitor rates vary over the course of the day (Hobbs et al., 2016) and between days of the week. Therefore, each sign was displayed for an entire week to account for those variations. Before the first presentation of a sign and between any two signs, there was also one week without any display, which acted as baseline assessments. Having control weeks between experimental weeks fulfilled two purposes: First, again, all time-connected differences in the baseline hand hygiene behavior of hospital visitors would be covered. Second, the mean patient hospitalization time at the facility was M = 4.6 days (SD = 4.8; range: 1.0 - 61.3). The majority of their visitors would only see one of the seven signs even if a patient stayed twice the average hospitalization time. The latter is necessary to minimize the probability of the effect of one sign influencing the effect of another one. The signs were displayed on a 32-inch full HD TV screen which was placed directly on top of the single alcohol-based hand-rub dispenser in the lobby. During the control phases, the TV was turned off. Pictures of the intervention setup can be found in the online supplement.

Procedure

Data were collected unobtrusive and anonymously with an electronic traffic monitoring system with two sensors (XOVIS PC2/PC2 UL – 3D, which are in compliance with the EU-DSGVO data protection regulation) installed at the lobby's ceiling. These types of sensors are often deployed in retail stores, airports, and train stations to reliably monitor people traffic. The electronic monitoring system yields two types of anonymous metadata: First, the event stream, which counts how many people pass over a predetermined line in a room, and second, the object stream, which determines peoples' direction of movement at the count line. In the present study, the sensors measured the traffic in the lobby and people approaching the hand-rub dispenser in the lobby. To measure the traffic in the lobby, the first count line stretched across the lobby about two meters (6.5 ft) in front of the dispenser. Everyone who entered the

hospital lobby through the main entrance to go to reception or directly to the wards needed to cross this line. The same was true for everyone who left the hospital through the main entrance. It should be noted that the electronic monitoring system could not distinguish between visitors and other groups of people. Most patients also enter the hospital through the main entrance. The hospital staff usually use the employee entrance; however, some staff members might occasionally walk through the lobby.

To measure the dispenser usage, a set of count lines was arranged in an approximately 30 cm-radius (11.8 inch) semicircle in front of the dispenser (see online supplements for a floorplan with count lines). The sensors recorded how often people entered or left the immediate dispenser area. The average of both counts (approaching and leaving the dispenser area) was used for further analysis, as there was a slight measurement error of 4.3% between the approach- and leave-count throughout the experiment. Measurement errors can sometimes occur when an object considerably bigger than the target area (e.g., a wheelchair) is recorded. Henceforth, this average will be called *dispenser usage* as it can be assumed people who stand directly in front of the dispenser actually use it. The 30 cm radius is too close to the TV set to provide a good view at the sign; therefore, it is highly unlikely that people would come so close only to have a better look at the picture. The two sensors were installed, and the accuracy of the recordings validated by specialists.

Originally, it was planned to additionally verify the chosen measure of dispenser usage with a dispenser-integrated mechanism counting how often the lever was pressed. However, after observing the behavior of visitors, it became clear that people considerably varied in how often and how strongly they pressed the dispenser lever when cleaning their hands (the mechanism only counts an action when the lever is pressed almost fully down). The same was also true for the amount of hand-rub (in ml) used, which is also often applied as a proxy measure for hand hygiene behavior. With mechanical dispensers, the amount of hand-rub in ml used by a person to clean their hands depends on how often and how strongly the lever is pressed. Therefore, both the dispenser-integrated count and the hand-rub amount in ml could not be used as reliable validation measurements for the number of people using the dispenser.

It should be noted that the present study did not take the quality of people's hand hygiene behavior (i.e., whether they were using enough hand-rub or if the hand-rubbing duration was adequate) into consideration.

Employing an electronic sensor system had two main benefits over direct observation: First, the Hawthorne effect—i.e., the change in behavior that arises from the mere awareness of being under investigation—can be reduced to a minimum. Second, it was the most cost-efficient method to have 24/7 observation throughout the 14-week field experiment. The sensor system provided accumulated dispenser usage and count data of people entering and leaving the hospital's lobby every 15 minutes, which represents the unit of analysis. Therefore, the dependent variable in the study was the dispenser usage rate in percent for every 15-minute interval recorded by the system. The usage rate per 15-minute interval was calculated by dividing the number of dispenser usages by the number of people entering and leaving the hospital's lobby and multiplied by 100 to gain a percentage. There had already been video surveillance in the lobby before the start of the experiment, therefore, no additional signs to point out surveillance were needed. The University of Regensburg's Research Ethics Committee waived the requirement for a full ethical review of the study as no personally identifiable data was collected. Additionally, both the University's Research Ethics Committee and the management team of the Rottal Inn Hospital dispensed with the requirement for informed consent as the experiment was of a passive nature.

Results

Over the entire study period, 246,098 people entering and leaving the hospital's lobby and 17,308 dispenser usages were recorded. In total, the electronic monitoring system provided sensor data from 9,259 intervals of 15 minutes (units of analysis). This accumulates to 13.8 weeks. Data were discarded for one hour around the time the display was changed in the lobby every week to avoid data recordings from the experimenter and data from visitors who might have been influenced by the experimenter's presence. This exclusion explains about 0.1 weeks missing from the 14 weeks in total. There was one technical issue on the first day of the first baseline week at which the sensor did not record data, which accounts for

another 0.1 missing weeks. Only in three out of the 9,259 cases did the system erroneously record more people approaching the dispenser than entering and leaving the lobby (error rate: 0.03%). These cases were excluded from the analysis. There were no technical problems besides. Only 15-minute intervals in which movement in the lobby was recorded were included in the analysis, leaving us with a sample size of 6,551 intervals. Often during the night no people entered or left the hospital, accounting for the intervals in which no movement was recorded. The average usage rate (arithmetic mean) during the entire study period was M = 6.4% (SD = 7.3).

The dependent variable in the study was the dispenser usage rate. For count and rate variables, the Poisson distribution rather than the normal distribution is the appropriate model for fitting data, especially if the data is heavily skewed to the right, which is often the case for count and rate data (Walters, 2007). The dispenser usage rate in the present study was indeed heavily skewed to the right (see online supplement for a histogram of the usage rate data over the entire study period). One crucial feature of Poisson models is the equality of the mean and variance functions, also known as the assumption of equidispersion (Cameron & Trivedi, 1986; Hilbe, 2014). Testing the assumption of equidispersion showed a sign of overdispersion in our data, which means that the variance of the Poisson model exceeds its mean (Cameron & Trivedi, 1986). To adjust for the overdispersion, a negative binomial regression model was chosen, which is recommended in the literature (e.g, Hilbe, 2014). The dispenser usage rate measure was neither truncated nor censored, which would violate the distribution assumption of the negative binomial regression model (Hilbe, 2014). Overall, a negative binomial regression model seems to fit the distribution of the dispenser usage rate data well.

First, it was tested whether there were any differences in the dispenser usage rate between the seven baseline weeks. Over the seven baseline weeks, 3,248 15-minute intervals with movements were recorded with 119,423 people entering and leaving the hospital's lobby, and 7,932 dispenser usages. The recorded numbers for each baseline week are displayed in the online supplement. Table 2 displays the results of the regression. To compare the mean usage rates from each baseline week against each other, a Tukey post-hoc test was performed

on the regression model. None of the contrasts showed significant differences. This indicates that the baseline dispenser usage rate did not vary significantly throughout the experiment. The average usage rate (arithmetic mean) during the control weeks was *M* = 6.0% (*SD* = 7.4). Figure 1 displays the mean dispenser usage rates of the seven baseline weeks.

Table 2

Predicting Dispenser Usage in the Baseline Weeks Against W1 Baseline

						95% CI for e^b	
Predictor	*b*	*SE*	*z*	*p*	e^b	LB	UB
Constant	1.83	0.06	29.77	<.001	6.24	5.55	7.06
W2 Baseline	-0.06	0.08	-0.67	.500	0.95	0.80	1.11
W3 Baseline	-0.12	0.08	-1.39	.166	0.89	0.76	1.05
W4 Baseline	-0.03	0.08	-0.32	.747	0.97	0.83	1.15
W5 Baseline	-0.07	0.09	-0.77	.440	0.94	0.79	1.11
W6 Baseline	0.03	0.08	0.34	.735	1.03	0.87	1.21
W7 Baseline	0.01	0.09	0.11	.914	1.01	0.86	1.19

Note. W = week; *b* = unstandardized coefficient; *SE* = standard error; z = *b/SE; p* = probability value; e^b = exponentiated regression coefficient; Log Likelihood = -9,290.62 (*df* = 8); AIC = 18,597; BIC = 18,645.92.

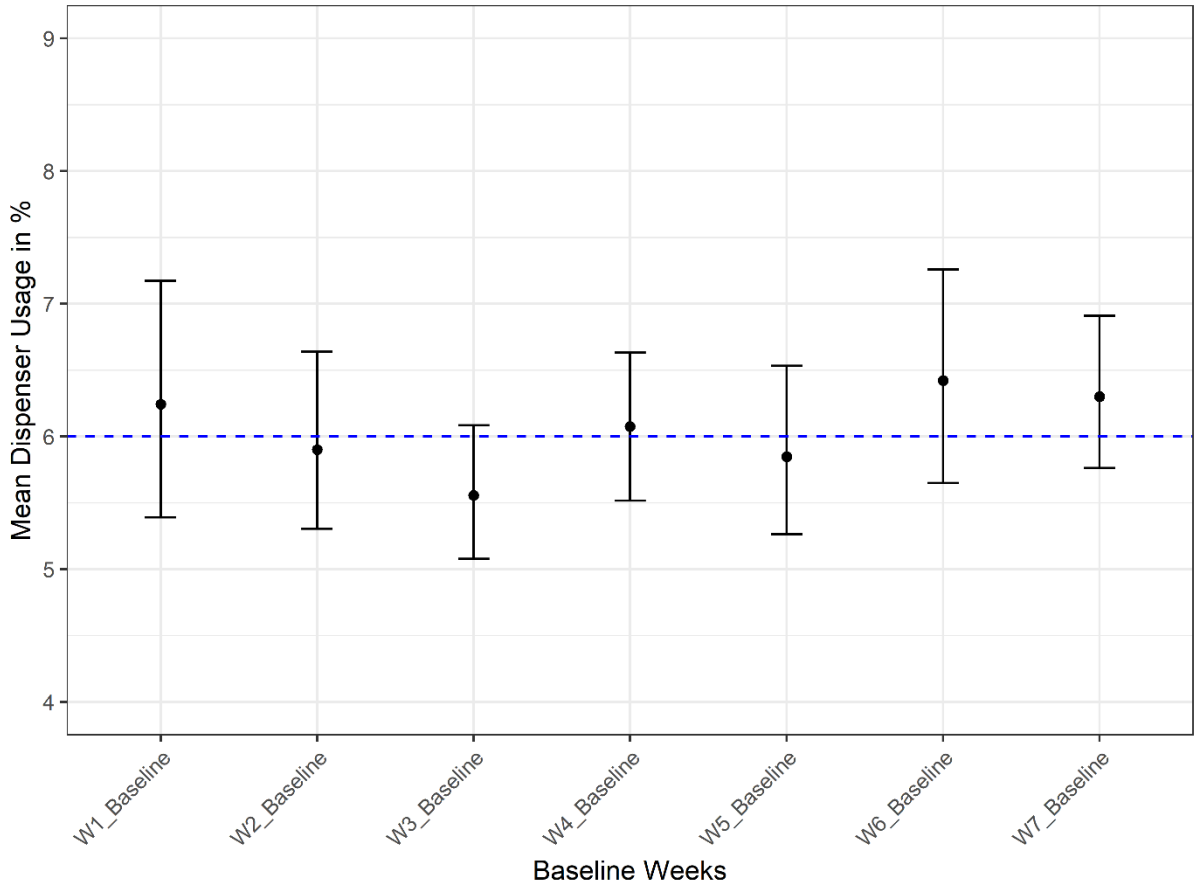

Figure 1. Mean (and the 95% confidence interval) dispenser usage rate in percent during the seven baseline weeks (W). Means are the average usage rate of all 15-minute intervals within each week. Usage rate per 15-minute interval was calculated by multiplying the number of usages within these 15 minutes by 100 and dividing it by the number of people passing by. The blue (dotted) line represents the grand mean over all seven weeks (average baseline usage rate).

Next, the effects of the seven signs on the dispenser usage were compared to the average baseline level. Over the seven experimental weeks, 3,303 15-minute intervals with movements were recorded with 126,675 people entering and leaving the hospital's lobby and 9,376 dispenser usages. The average usage rate (arithmetic mean) during the experimental weeks was *M* = 6.7% (*SD* = 7.2). Again, the recorded numbers for each baseline week are displayed in the online supplement. The regression model included the average baseline and the seven signs used in the intervention weeks. Table 3 displays the results of the regression. Two out of the seven messages showed a statistically significant increase in dispenser usage rate compared with the average baseline usage rate. Overall, the sign based on the *authority* principle (*M* = 7.7, *SD* = 7.4) was the most effective, with a 27.8% (95% CI [16.8%, 38.7%]) relative increase compared with the baseline usage rate. Additionally, a significant increase in

the dispenser usage rate was found for the sign based on the principle of *social-proof* (*M* = 6.9, *SD* = 7.3). There was no significant increase in the dispenser usage in the weeks with the signs designed according to the principles of *reciprocity* (*M* = 5.9, *SD* = 6.5), *consistency* (*M* = 6.4, *SD* = 6.4), *unity* (*M* = 6.6, *SD* = 7.2), *liking* (*M* = 6.6, *SD* = 6.7), and *scarcity* (*M* = 6.6, *SD* = 8.4). To compare the mean usage rates from the seven signs against each other, a Tukey post-hoc test was performed on the regression model (only experimental weeks included). The usage rate in the week during which the *authority* sign was displayed significantly outperformed the usage rate during the week of the *reciprocity* sign (*p* = .007). None of the other contrasts showed significant differences. This post-hoc analysis is confirmed by the confidence intervals around the mean usage rates displayed in Figure 2.

Table 3

Predicting Dispenser Usage in the Experimental Weeks Against the Baseline

						95% CI for e^b			*95% CI for RI*	
Predictor	*b*	*SE*	*z*	*p*	e^b	LB	UB	RI	LB	UB
Constant	1.80	0.02	84.68	<.001	6.05	5.80	6.31	---		
W1 Reciprocity	-0.03	0.06	-0.51	.608	0.97	0.86	1.09	-2.3%	-12.0%	7.5%
W2 Consistency	0.05	0.06	0.84	.400	1.05	0.94	1.18	5.9%	-3.6%	15.3%
W3 Unity	0.09	0.06	1.56	.119	1.10	0.98	1.24	10.7%	-0.3%	21.6%
W4 Social-proof	0.13	0.06	2.14	.032	1.14	1.01	1.28	14.7%	3.4%	26.0%
W5 Liking	0.08	0.06	1.38	.168	1.09	0.97	1.22	9.5%	-0.7%	19.7%
W6 Authority	0.24	0.06	4.10	<.001	1.27	1.13	1.42	27.8%	16.8%	38.7%
W7 Scarcity	0.09	0.06	1.57	.117	1.10	0.98	1.24	10.7%	-2.0%	23.3%

Note. W = week; *b* = unstandardized coefficient; *SE* = standard error; z = *b/SE; p* = probability value; e^b = exponentiated regression coefficient; RI = relative increase is the arithmetic mean of the difference between each,15-minute interval's usage rate and the average baseline usage rate in %; Log Likelihood = -19,072.1 (df = 9), AIC = 38,162; BIC = 38,223.28.

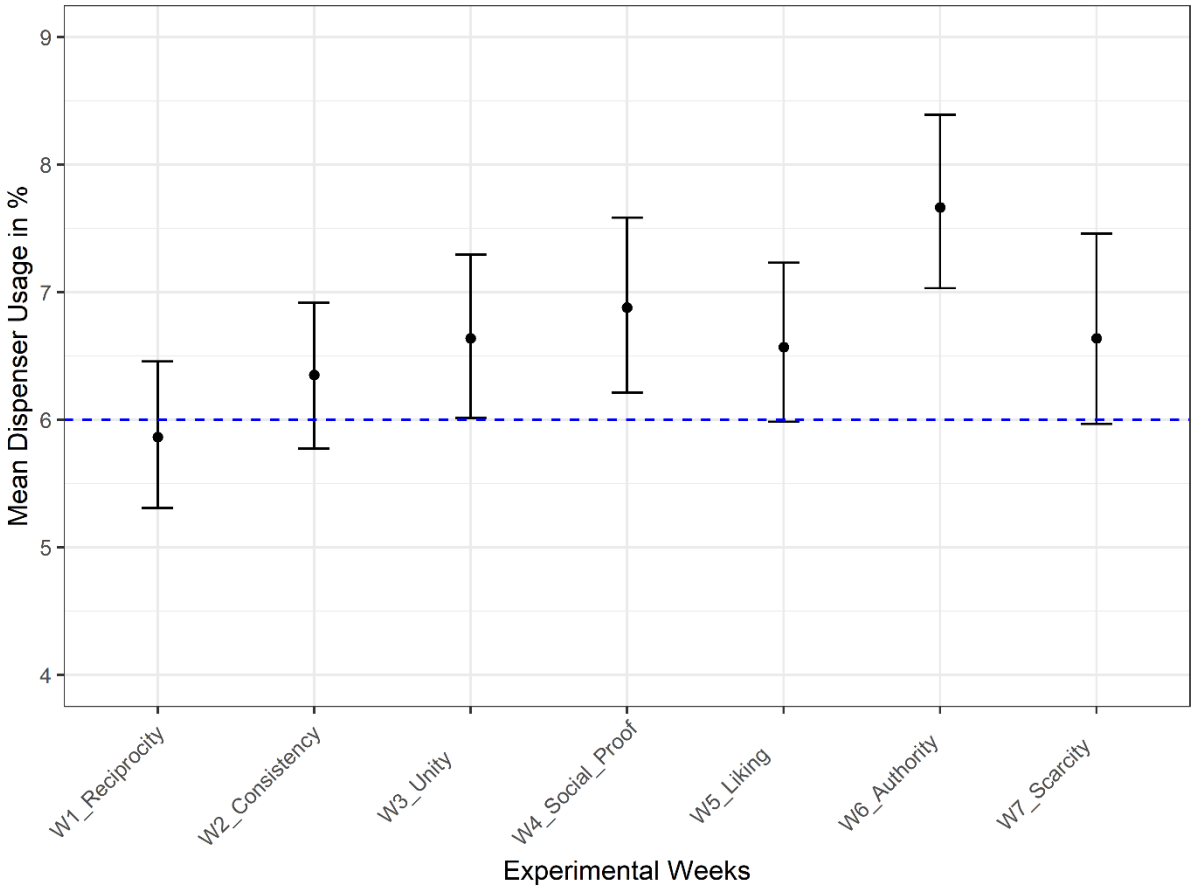

Figure 2. Mean (and the 95% confidence interval) dispenser usage rate in percent during the seven experimental weeks (W). Means are the average usage rate of all 15-minute intervals within each week. Usage rate per 15-minute interval was calculated by multiplying the number of usages within these 15 minutes by 100 and dividing it by the number of people passing by. The blue (dotted) line represents the average baseline usage rate.

The two signs (*authority* and *social-proof*) that significantly outperformed the average baseline were compared against the baseline weeks directly preceding each sign respectively (W6 Baseline for *authority* and W4 Baseline for *social-proof*). According to the Mann-Whitney U test, the dispenser usage rate of 7.7% in the week with the *authority*-sign displayed is significantly higher than the baseline usage rate in W6 Baseline of 6.4% ($p < .001$). Additionally, the dispenser usage rate of 6.9% in the week with the sign designed according to the principle of *social-proof* displayed is significantly higher than the W4 Baseline usage rate of 6.1% ($p = .019$). When averaging all experimental conditions, the dispenser usage rate increased by 11.0% (95% CI% [7.0%, 15.1%]) from the baseline usage rate.

To investigate whether there was a social effect on the dispenser usage rate caused by the number of people entering or leaving the hospital, a method used by Judah et al. (2009) was adopted. The correlation between the number of people entering and leaving the hospital

lobby with the dispenser usage rate for all episodes was calculated. There was a significant positive trend for the dispenser usage rate to increase during intervals with more people being recorded at the lobby (r = .15; p < .001; 95% CI [.12, .17]). This trend was slightly stronger during the experimental weeks (r = .17; p < .001; 95% CI [.13, .20]) than during the baseline weeks (r = .12; p < .001; 95% CI [.09, .16]). Table 4 depicts the correlations between the recorded number of people entering and leaving the lobby with the dispenser usage rate for each sign separately. We found significant positive correlations for all but one sign (*unity*). Additionally, the recorded number of people entering and leaving was split at the Median (*Mdn* = 38). Intervals below the median were classified as *low traffic* while intervals above the median were classified as *high traffic*. The dispenser usage rate was significantly higher in *high traffic* intervals than in *low traffic* intervals for all seven signs as well as the average baseline (see Table 4). Overall, there was a social effect in both the baseline and the experimental weeks. This means that in intervals with more people entering and leaving the hospital lobby, the hand-rub dispenser usage rate was generally higher.

Table 4

Results of the Social Effect Analyses

	Pearson's Correlation				Mann-Whitney U test				
			95% CI					*95% CI*	
	r	*p*	LB	UP	M_{Low}	M_{High}	*p*	LB	UP
Average Baseline	.12	< .001	.09	.16	5.3	6.9	< .001	-3.64	-3.05
W1 Reciprocity	.20	< .001	.12	.29	5.1	6.9	< .001	-3.92	-2.11
W2 Consistency	.25	< .001	.17	.33	4.8	7.8	< .001	-4.84	-3.24
W3 Unity	.07	.126	-.02	.16	6.0	7.2	< .001	-3.92	-2.34
W4 Social-proof	.12	.013	.02	.21	6.1	7.4	< .001	-4.75	-2.62
W5 Liking	.18	< .001	.09	.27	5.4	7.7	< .001	-4.93	-3.49
W6 Authority	.19	< .001	.10	.27	6.4	8.8	< .001	-5.45	-3.48
W7 Scarcity	.13	.005	.04	.22	5.9	7.4	< .001	-4.37	-3.06

Note. r = Pearson's correlation coefficient; p = probability value; M_{Low} = Arithmetic mean of the usage rates of all 15-minute intervals with low traffic (below median); M_{High} = Arithmetic mean of the usage rates of all 15-minute intervals with high traffic (above median).

Discussion

In the present study, it was explored whether signs designed according to Cialdini's principles of persuasion could improve visitors' hand hygiene behavior at a hospital's entrance. The 6.0% baseline usage rate of the dispenser was higher compared to previous observations

(Birnbach et al., 2012; Pittz, 2009), but showed considerable room for improvement. The baseline usage did not significantly vary over time, indicating that no confounding variables (e.g., weather) seemed to influence visitor behavior. The consistency in baseline usage affirms our claim that the seven signs' effects are independent. Two of the seven signs significantly increased the dispenser usage rate compared to the average baseline level. The sign based on the *authority* principle led to the highest dispenser usage rate of 7.7%. This constitutes a relative increase of 27.8% (95% CI [16.8%, 38.7%] from the average baseline level of 6.0% and a relative increase of 19.8% (95% CI [9.5%, 30.1%]) from the baseline usage rate of 6.4% directly preceding the sign at baseline week six (W6 Baseline). The second sign that significantly outperformed the baseline dispenser usage rate was based on the principle of *social-proof* with a dispenser usage rate of 6.9%. It showed a relative increase of 14.7% (95% CI [3.4%, 26.0%]) from the average baseline level of 6.0% and a relative increase of 12.8% (95% CI [1.7%, 23.9%]) from the baseline usage rate of 6.1% directly preceding the sign at baseline week four (W4 Baseline). The dispenser usage rate at the weeks with the other signs being presented did not differ statistically significant from the baseline level. The relative increases in dispenser usage ranged between -2.3% and 10.7% for these five signs. As in Judah et al.'s (2009) experiment, the data showed a social effect for people's hand hygiene behavior at the hospital lobby, i.e., a significant positive trend for the dispenser usage rate during intervals with more people being recorded in the vicinity. It can be assumed that people are more likely to clean their hands when they see other people using the dispenser (i.e., social-proof). This trend was even slightly stronger during the experimental weeks than during the baseline weeks. However, the social effect in the present study was considerably smaller than in Judah et al.'s work. One speculation for this difference could be that people might expect to get more negative judgment when being observed to abstain from washing their hands at a public restroom in comparison to not using the hand-rub dispenser at a hospital lobby. Finally, the social effect was not stronger for more effective signs, as was the case in the study conducted by Judah and colleagues.

The relative increases in hand-rub dispenser usage found in the present study are slightly higher compared to a similar previous study, in which text-based persuasive messages were displayed at highway service station restrooms to improve handwashing (Judah et al., 2009). Judah and colleagues reported relative increases in soap usage rates between -4.8% and 12.1%. In their study, the four most assimilable messages to the signs tested in the present experiment were based on two theoretical domains—*norms/affiliations* and *status/identity*—and resulted in relative increases between 2.9% and 12.1%. The most straightforward reason for the overall higher relative increases in hand hygiene behavior in the present study is that the baseline level usage rates in Judah et al.'s experiment were considerably higher, ranging at 31.7% (male restrooms) and 65.1% (female restrooms) compared to the 6.0% in our field experiment. The present study's results can also be compared with the outcomes of Grant and Hofmann's (2011) work, which tested the effect of norm-based signs emphasizing either patient safety or personal safety on hand hygiene product use and adherence to hand hygiene guidelines among hospital workers. For the patient safety sign, they found a 45.4% relative increase in product use and a 10.5% relative increase in observed adherence. In the wards with the personal safety signs being displayed, both measures slightly decreased (-4.3% and -0.4% respectively). Again, their baseline usage/adherence levels were higher than in the present study. The most similar set-up compared the effect of a freestanding hand-rub dispenser with and without a sign claiming that hand hygiene was mandatory for visitors (Birnbach et al., 2012; Birnbach et al., 2017). The dispenser usage rate increased by 25.1% from 9.3% to 11.7% when the sign was present. However, this increase was not statistically significant, which might have been caused by low statistical power. Overall, the relative increases found in the present study are within the range of other comparable research results. These findings are further evidence that signs can lead to significant improvements in hand hygiene behavior. However, it also shows that sign-based interventions seem to be limited in their effectiveness.

The findings of the present field experiment also underline important implications for designing health and safety interventions. Signs *per se* do not change behavior by merely

attracting attention (see also Joffe, 2008). The signs' capability to trigger the intended principle and in turn produce an automatic reaction might rely on several factors like the relevance and trustworthiness of the conveyed message, its framing, tone, and context-fit (Fishbein & Cappella, 2006; Joffe, 2008). These factors could help to explain why the *authority* sign showed the most substantial improvement in the usage rate compared to the baseline level. Historically, the default in medical situations has been to comply with physicians' recommendations because of their higher level of expertise (Frosch et al., 2012; Haug & Lavin, 1981). Therefore, when the hospital's medical director advises visitors to clean their hands, the automatic reaction should be to follow the doctors' advice. However, the paternalistic physician-patient perspective, which puts the patient in a passive position towards the doctor, is transforming. The role model for the physician-patient relationship is trending towards a more equal partnership and a shared decision-making-process (Schäfer, 2017; Thielscher & Schulte-Sutrum, 2016). Still, a recently published paper found that among German patients with elevated heartrate, the recommendation of a physician is the critical mediator for treatment selection (Schmieder et al., 2019). Patients reported doctors to be their main source of information regarding medical issues and their key influencers on therapy related decisions. Therefore, it can be assumed that the principle of *authority* was effectively activated in the present study by a good fit between the message and the context.

A similar set of assumptions might be applied to the *social-proof* sign. Other hospital visitors might act as valid and trustworthy peers against whom to compare one's own behavior. People often involuntarily use the behavior of peers as a reference and usually do not want to deviate from this norm (Cialdini & Goldstein, 2004; Schultz et al., 2007). Again, it can be assumed that the *social-proof* principle was effectively activated through the sign signaling that other hospital visitors clean their hands. This might have led to an increased level of compliance with the normative behavior of using the dispenser. Additionally, the evidence for the social effect found in the present study is a further example for the *social-proof* influence on people's behavior.

The factors mentioned above could also help to explain why some signs were less persuasive. For example, depicting people in traditional local outfits which should activate a sense of unity might fail to convey meaningful information because it does not fit into the hospital context and some people might not identify with the local group. Therefore, the *unity*-sign might have been less potent in triggering the intended principle of persuasion and in turn did not produce a strong automatic reaction. More research is needed to better understand how the fit between target behavior, message, and situation interact to activate the intended principles effectively. Also, future research should focus on testing experimentally if the principles of persuasion indeed activate an automatic response or trigger deliberate thinking in this specific context. A further implication of this study is that even when an intervention is grounded in theory, putting considerable effort into planning and piloting the intervention material in the field before a large roll-out is necessary to understand the casuistic factors at play (see also Fishbein et al., 2002). Additionally, health and safety interventions using signs can also be categorized as *nudging*, i.e., a slight push to encourage desired behavior (Caris et al., 2018). When an intervention is designed to nudge people towards a certain behavior, potential risks and unintended consequences should always be assessed *a-priori*. For the present study, the potential risk for hospital visitors being encouraged to sanitize their hands was evaluated to be no more than minimal. No meaningful unintended negative consequences were anticipated. Triggering automatic reactions through nudging has been criticized for being manipulative and undermining personal autonomy (see Schubert, 2015, for a discussion on the ethics of nudging). However, the present intervention's intention in improving hand hygiene behavior in hospitals was not concealed, and as the overall low usage-rate indicates, people's personal decision whether to use the dispenser or not was uncompromised.

The present study had several limitations. First, due to the monitoring system, it was impossible to control if the signs only affected visitors. While employees use another entrance, some hospital staff still pass by every day. Additionally, most of the patients enter the hospital through the main entrance. This is not a problem, as patients should also clean their hands at the entrance, but some of the messages explicitly mentioned visitors, so patients might not

have felt targeted. Also, there is a cafeteria next to the hospital's entrance. Part of the traffic recorded was not from people entering or leaving the hospital but from people going to the cafeteria. As this was true for both the baseline weeks and experimental weeks, it does not affect the interpretation of our results. The additional traffic might make the effect of the intervention on visitor hand hygiene behavior look smaller than it was. Second, with the monitoring system, it was not possible to test whether people who entered the hospital with the signs in direct view used the hand-rub dispenser more often than people who left the hospital without the sign in direct view. This should be tested in a subsequent study. Third, it cannot be guaranteed that the sensor's recording whenever people entered or left the immediate dispenser area is a perfect representation of actual dispenser usage. However, sample observations have shown that people who approach the dispenser within the sensor's radius also use it. Fourth, no assertion about the quality of hand hygiene behavior (i.e., if enough hand-rub was used and if it was properly spread over the hands) can be made. As mentioned above, observed visitors considerably varied in how often and how strongly they pressed the dispenser lever when cleaning their hands. Future research should investigate if the quality of visitors' hand hygiene behavior affects infection prevention. Fifth, even though the majority of people entering and leaving the hospital lobby saw only one sign, giving the range of hospitalization time per patient, some visitors might have seen more than one sign. Still, as the baseline usage rate did not increase over time, the potential carry-over effect is negligible. Sixth, we do not know if the signs were equally effective in activating the intended principle of persuasion. In the material pre-test, the participants were asked to rate whether the messages were consistent with the proposed principles and to rate whether the pictures were consistent with the above-stated messages. This approach was chosen to make sure that the message to be conveyed was complemented by the image to a high degree. However, the final signs were not tested on their effectiveness in activating the intended principle. In subsequent research, the intervention material should be more thoroughly validated (see Sassenrath et al., 2016, for one of the few examples of a diligent intervention material pre-test in this context). Finally, the overall increase in dispenser usage rates was rather moderate.

However, to put the figures in perspective, in an average week, about 17,580 people passed by the dispenser. A usage rate of 6.0% equals 1,055 dispenser usages, while 7.7% (in the *authority*-sign week) represents 1,354 usages. It is assumed that the effect does not substantially decline over time since the visitors are constantly changing. Extrapolated to one year, this would mean that placing a single sign based on the authority principle in the hospital lobby might result in the dispenser being used about 15,548 times more annually. Considering the scale of the negative consequences for every patient affected by a healthcare-associated infection, this easy-to-administer and cost-efficient intervention might have an impact on patient safety in healthcare facilities. However, though several studies have reported a decline in infection rates after hand hygiene interventions targeting visitors and patients (e.g., Cheng et al., 2007; Gagne et al., 2010), it should be noted that there is no published evidence to indicate that improving visitors' hand hygiene behavior at a hospital lobby reduces healthcare-associated infection rates. It could be only speculated whether the intervention had an effect on visitors' hand hygiene behavior closer to the point-of-contact with the patients on the wards by raising awareness on the topic. Further research should be conducted to test whether there is a carry-over effect from the entrance to the on-ward behavior. It should also be explored if placing the signs at the wards' entrances or within the patient rooms could improve visitors' hand hygiene behavior in closer proximity to the actual point-of-contact with the patients.

To our knowledge, this is the first study to systematically test Cialdini's seven principles of persuasion on improving hand hygiene in hospitals among visitors. Signs based on the *authority* and *social-proof* principles substantially increased dispenser usage at the facility's entrance. The results indicate that a straightforward and cost-efficient intervention can initiate expedient behavior change in a natural setting. However, the results also showed that the intervention material needs to be carefully planned and pre-tested. More research is needed to find optimal ways to enhance this positive effect and to see whether the findings can be generalized in other healthcare environments.

General Discussion

Summary of Findings

Study 1: The first study had three main goals: first, to find a suitable theoretical model to explain self-reported hand hygiene behavior among hospital patients and visitors; second, to identify the critical facilitators and barriers to predicting their hand hygiene behavior; and third, to compare the findings from patients and visitors with healthcare professionals.

To achieve these goals, patients and visitors in four German hospitals were surveyed, and we qualitatively compared their results with the existing literature on healthcare worker's hand hygiene compliance. The questionnaires used in the study were designed according to three well-established theoretical models: (1) Theory of Planned Behavior (TPB, (Ajzen, 1991)); (2) Health Action Process Approach (HAPA (Schwarzer, 1992, 2001; Schwarzer et al., 2011); and (3) Theoretical Domains Framework (TDF (Cane et al., 2012; Michie et al., 2005)). The questionnaire data were analyzed using structural equation modeling (SEM). The results showed that the path structures outlined according to TPB and TPB fit well with both patients' and visitors' data. However, the initially proposed HAPA path structure showed a poor model fit among both target groups. Therefore, the HAPA path structure had to be modified. After considering the theoretical relevance and statistical modification indices of all theoretical constructs, the variable planning was removed from the HAPA models. The variable action control was allowed to correlate both with the self-reported hand hygiene behavior and behavioral intention. The modified HAPA models fit well with both data sets.

To summarize the study's goal attainment: Frist, the results showed that all three theoretical models explained a significant proportion of the variance in patients' and visitors' self-reported hand hygiene behavior. The TDF-model accounted for the most considerable portion of variance, with 53% among patients and 60% among visitors. Therefore, TDF was considered the most suitable theoretical model to study and explain the participants' hand hygiene practice. The TPB-model explained 40% of the variance in self-reported hand hygiene

behavior among patients and 55% among visitors. The modified HAPA-model accounted for 44% of the variance among patients and 37% among hospital visitors.

Second, the data analysis showed that behavioral intention is a robust but imperfect predictor for the reported hand hygiene practice. These results verify the importance of intention formation for behavior change but also show that the HAPA model's proposed post-intentional constructs have not fully closed the intention-behavior gap. Besides intention, we identified two broad clusters of critical facilitators and barriers to predicting patients' and visitors' behavior. The first cluster consists of constructs relevant for self-regulation: perceived behavioral control (PBC); self-efficacy; action control; and memory, attention, and decision processes. The second cluster contains the two social influence process constructs of subjective norm and role and identity.

To attain the third goal, we compared the present study's results with published research on facilitators and barriers to healthcare workers' hand hygiene. Research using the TPB to explain healthcare workers' hand hygiene compliance identified PBC and intention as the most critical determinants (Eiamsitrakoon et al., 2013; Erasmus et al., 2020; McLaws et al., 2012; O'Boyle et al., 2001; Pessoa-Silva et al., 2005; Pittet et al., 2004; Sax, Uckay, et al., 2007; Whitby et al., 2006). This corresponds well to our findings among patients and visitors. From the HAPA model constructs, self-efficacy and action control are most strongly associated with hand hygiene behavior or intention across healthcare professionals (von Lengerke et al., 2015) and the patients and visitors surveyed for the present study. However, our results showed little evidence for the resources and barriers construct to be a good predictor for acceptable behavior, which has been identified as a critical factor among healthcare workers. Consistent with the research using the TDF to explain healthcare workers' hand hygiene behavior (Dyson et al., 2013; Fuller et al., 2014; Smith et al., 2019), the constructs of role and identity as well as memory, attention, and decision processes were also found to be strong predictors among patients and visitors. Contrary to the other studies, the constructs of knowledge and skills, environmental context and resources, and beliefs about consequences were not identified as critical for patients' and visitors' hand hygiene practice. This assessment

showed that the essential determinants for healthcare workers' and laypeople's hand hygiene behavior in hospitals are similar but not identical. The similarities among both groups indicate that successful behavior change interventions aiming to improve healthcare workers' hand hygiene behavior should also be applied for patients and visitors, and vice versa. However, the differences between the two groups should be analyzed further.

We assume that some of these differences might have been caused by the research method employed in different publications, which already seemed to explain some variations within the healthcare workers' literature. A few of these studies used qualitative methods to evaluate the model's constructs (e.g., Fuller et al., 2014; Whitby et al., 2006). Therefore, we planned to compare the present study's results—in which a structured questionnaire format was used to measure the model components—to responses patients and visitors gave in an open-answer format in the second study. We wanted to examine whether these two methods would identify similar critical determinants of hand hygiene behavior. Besides the method of measuring the theoretical constructs, the method of measuring the behavior itself might also explain some of the differences in the critical determinants for hand hygiene behavior between healthcare workers and non-professionals. The majority of studies included in our comparison used self-reported instead of observed hand hygiene behavior as their dependent variable (see Table 4, Study 1). Relying on self-reported data is easier and cheaper than gathering observation data. However, people often overestimate their hand hygiene behavior in self-reports (Jenner et al., 2006; O'Boyle et al., 2001). Therefore, we intended to use observed hand hygiene behavior as our outcome measure in the second study. Since observing patients in their rooms is both resource-intensive and can feel intrusive for the observed person, we focused on visitors' hand hygiene practice at the hospital's entrance.

Study 2: Consequently, the second study also had three main goals: first, to assess whether hospital visitors' self-reported hand hygiene behavior differed from their observed action. The second goal—similar to the previous study—was to find a suitable theoretical model to explain visitors' observed hand hygiene behavior. The third goal was to compare the

predictions derived from visitors' theory-coded responses for cleaning or not cleaning their hands in the open-answer format and the structured questionnaire-format answers.

To achieve these goals, visitors' hand hygiene behavior was observed in three German hospital lobbies. After taking note of their behavior, visitors were invited to participate in a short survey. Visitors who agreed to the survey were asked to self-report if they used the hand-rub dispenser in the lobby and explained why they did or did not in an open-answer format. The rest of the questionnaire is described in Study 1. Afterward, the participants' open-answer explanations were coded independently by three trained raters according to the definitions of the TPB, HAPA, and TDF model constructs. Each answer was coded separately for each theoretical model. The inter-rater reliability, assessed through the intraclass correlation coefficient (ICC), was good to excellent. Any remaining disagreements were solved through discussion. Binomial logistic regressions were used to compare the model fits and test which constructs significantly predicted dispenser usage.

To summarize the study's goal attainment: First, the findings indicate that hospital visitors significantly overreport their hand hygiene behavior compared with observation data. Around 15% of the surveyed visitors professed to have used the hand-rub dispenser in the lobby, while the observation showed that they did not. Our results match previous research showing the same effect among healthcare professionals (Jenner et al., 2006; O'Boyle et al., 2001). These findings underline the importance of using objective measurements when studying hand hygiene behavior both among healthcare professionals and non-professionals because the self-reported data is likely biased.

Second, the analysis showed that a greater percentage of the explanations could be allocated to the TDF (83.5%) than to the HAPA (73.5%) and the TPB (49.5%). This finding showed that the more detailed the model is, the more explanations matched with theoretical constructs. The model fit indices suggest that the HAPA and TDF regressions fit the data especially well. Considering that the TDF model allowed for allocating more explanations to its constructs than HAPA, we think it is the most suitable theoretical model to understand the facilitators and barriers to hospital visitors' hand hygiene behavior. This conclusion is also

consistent with the results from Study 1. All four TPB constructs and the five HAPA constructs included in the regressions (some constructs could not be included because they were not mentioned by the visitors) emerged as statistically significant predictors for observed hand hygiene behavior. Five of the nine TDF constructs included in the regression emerged as significant predictors: knowledge and skills; motivation and goals; memory, attention, and decision processes; environmental context and resources; and social influences.

Third, comparing the prediction of the theory-coded responses in the open-answer format to the structured questionnaire-format yielded some interesting insights. The TPB results from Study 2 corresponded well with the results from Study 1. However, subjective norm and not PBC emerged as the strongest predictor in the second study. Overall, the TPB results from Study 1 and Study 2 agree with most of the research on healthcare workers' hand hygiene compliance. The HAPA results were more complex to compare because the construct of self-efficacy was not included in the regression in Study 2, and the construct of planning was not included in the SEM model in Study 1. In both analyses, the constructs of outcome expectancies, risk perception, and action control were significantly associated with visitors' hand hygiene behavior or intention. In Study 2, risk perception and not action control (as in Study 1) had the strongest effect. Since the only healthcare-worker-study that had behavior as an outcome variable did not include pre-intentional constructs, we can only conclude that the construct of action control is the most consistent predictor for hand hygiene behavior in the available literature. Only the two TDF constructs of knowledge and skills and memory, attention, and decision processes significantly predicted hand hygiene behavior in both studies. The findings from Study 2 are overall more consistent with the results from research on healthcare workers' hand hygiene behavior (Dyson et al., 2013; Fuller et al., 2014; Smith et al., 2019) than the results from Study 1. This confirms the assumption that the method used to measure the model-constructs (qualitative or quantitative approach) and hand hygiene (self-reported vs. observed behavior) affects the study's outcomes. Nevertheless, using both the coded open-answer explanations and structured questionnaire scales as predictors for visitors'

hand hygiene behavior produced reasonably consistent results. Therefore, both approaches seem to be acceptable methods to measure determinants for people's hand hygiene behavior.

Overall, Studies 1 and 2 deliver a comprehensive insight into the psychological determinants of hand hygiene behavior in healthcare facilities among patients and visitors. The following conclusions can be drawn from the two cross-sectional, correlative studies: (1) Relying solely on people's self-reports when studying hand hygiene behavior is not ideal because people overreport their hand hygiene behavior. Therefore, the effectiveness of an intervention designed to improve hand hygiene practices should be judged by objectively measured data. (2) The TDF-construct of memory, attention, and decision processes is among the four constructs that consistently emerged as essential predictors among patients, visitors, and healthcare workers. Therefore, hand rub dispensers should be placed at clearly visible and easily accessible locations to prevent forgetting and facilitating usage. (3) Action control (HAPA) and PBC (TPB) are another two of the four constructs that surfaced as good predictors for hand hygiene behavior among all groups. Therefore, behavior change interventions should be designed to raise awareness about pathogen transmission and explain how easy it is to perform adequate hand hygiene, which should increase peoples' perceived agency. (4) The TPB-construct of subjective norm is the fourth consistent predictor for hand hygiene behavior among non-professionals and professions in most studies. Consequently, behavior change interventions should be designed to use social influence processes, e.g., intervention materials and reminders should contain messages indicating that hand hygiene is the norm among people in the healthcare facility. In the third and final study of the current research project, these four learnings were considered for the design and implementation of an experimental intervention to increase visitors' rate using a hand rub-dispenser in a hospital lobby.

Study 3: The third study's main goal was to test whether an evidence-based intervention using persuasive messages could improve the observable hand hygiene behavior among visitors in a hospital lobby. This intervention strategy was derived from the insights gathered in Studies 1 and 2. Placing large, attention-grabbing signs above an easily accessible, centrally placed hand-rub dispenser should act as a salient visible reminder to

visitors and reduce environmental friction that prevents people from using the dispenser. The messages displayed on the signs were designed to raise awareness that visitors are a potential vector for pathogen transmission and should sanitize their hands. Additional information next to the dispenser showed how to perform adequate hand hygiene in three easy steps. The signs utilized the effectiveness of social influence processes by displaying images and messages designed according to seven fundamental persuasion principles (Cialdini, 2007, 2016). Additionally, we wanted to test whether the dispenser usage rate was significantly associated with the number of people entering or leaving the hospital (i.e., a social effect).

To measure the principles' effectiveness, each sign was displayed precisely for one week. There was always one week without any display before/between any two signs to collect baseline data. The number of people entering and leaving the lobby and the dispenser usage rate were measured unobtrusively and anonymously via an electronic traffic monitoring system installed on the lobby's ceiling. According to the monitoring system, 246,098 people moved through the lobby and the dispenser was used 17,308 times within the 14-week field experiment. Two negative binomial regression models were calculated to compare the baseline and the experimental data.

The data analysis showed that the baseline dispenser usage rate was 6.0%, which is slightly higher than most usage rates published in other studies investigating people's hand hygiene behavior at hospital entrances (see Table 1, Introduction). According to the first binomial regression, there was no significant variation in dispenser usage between the seven baseline weeks. This has two important implications: First, the visitors' behavior seemed unaffected by potential confounding variables. Second, the effect each sign had on the hand hygiene rate in one week was independent of the other signs, which is essential for the interpretation of the experimental data.

From the seven signs tested in the experiment, the presentation of two led to a significantly increased dispenser usage rate compared to the average baseline. The first of these effective signs was based on the authority principle, with a dispenser usage rate of 7.7%, which was the highest throughout the study period. An increase from 6.0% (average baseline)

to 7.7% (authority) corresponds to a relative increase in dispenser usage of 27.8%. The second effective sign was based on the social-proof principle and showed a dispenser usage rate of 6.9%. Its presentation caused a relative increase of 14.7% from the average baseline usage rate. Unfortunately, the other five signs' display did not significantly increase the dispenser usage rate compared to the baseline level. For these five signs, the relative increases in dispenser usage ranged between -2.3% and 10.7%.

The data analysis confirmed our assumption that the dispenser usage rate was associated with the number of people present in the hospital lobby, i.e., we found evidence for a social effect. There was a significant positive correlation between the dispenser usage rate and a higher number of people being recorded in the vicinity. We assume that individuals are more likely to use the dispenser when they see other people doing it (i.e., social proof).

Altogether, the findings from Study 3 suggest that an easy-to-administer and cost-efficient sign-based intervention can facilitate a measurable improvement in the hand hygiene behavior of hospital visitors in a natural setting. Considering that even much more elaborate behavior change interventions can be prone to failure by comparison, these results underline the value of planning an intervention based on theoretical and empirical knowledge regarding the critical facilitators and barriers to the behavior in question. However, the findings from Study 3 also show that even when an intervention is evidence-based, its execution needs to be meticulously planned and pre-tested.

Limitations

Study 1: The first study's most substantial limitation is using self-reported hand hygiene behavior as the dependent variable. Previous research had already shown that self-reported hand hygiene compliance among healthcare workers is generally overrated (e.g., Jenner et al., 2006; O'Boyle et al., 2001). In Study 2, we confirmed that visitors also overrate their hand hygiene practice in hospitals. Therefore, future research should validate our findings using observed behavior as the outcome measure among patients and visitors. A second major limitation is the psychometric quality of some of the scales used in the HAPA and TDF questionnaires. The CFAs revealed that items from some scales did not load well on a factor,

which forced us to choose a single or two items to represent the construct, which is not ideal and only captures a narrow bandwidth of the theoretical construct. Thus, more research is needed to improve these scales' quality or create new universally applicable questionnaires. Third, a cross-sectional study design was employed. For this reason, we cannot make any statements about the causal effects at play. However, the causal directions proposed in the three theoretical models have been verified in other research. Fourth, we do not know if our findings can be generalized for different regions and countries because we only collected data in four German hospitals located within a 100km radius. Fifth and finally, the survey was conducted before the beginning of the COVID-19 pandemic in 2020. It is highly likely that hospital patients and visitors are now more sensitized about the importance of adequate hand hygiene. Future research should be conducted once the pandemic is over to validate the findings. The last three limitations of Study 1 also apply to Study 2, and the COVID-19 constraint also applies to Study 3.

Study 2: In addition to the three previously mentioned limitations, Study 2 has several other limitations. First, some TDF-construct components overlap, making the coding of the visitors' explanations for using or not using the dispenser challenging. We coded explanations falling into one of these overlapping components into all relevant constructs. Further development of the TDF should focus on making the constructs more delimitable and, in turn, easier to deploy for research and practice. Second, many explanations provided by the visitors tended to be short, lacked detail, and were sometimes slightly ambiguous. This made the coding process more difficult for the raters. Having said that, the results showed excellent inter-rater reliability, which indicates that the explanations were coded consistently by the raters. Third, the visitors gave their open answers for using or not using the dispenser after the behavior had occurred. Therefore, the explanations might be more of a post-hoc rationalization than the actual reason for their action. However, this is almost unavoidable when using self-reported data because people often think about their past actions when considering a future behavior. Finally, numerous visitors who did not use the dispenser in the lobby claimed to use one later in the ward or the patient room. We cannot verify if they followed up on their claims

because the research assistants did not track the visitors. Future research should explore visitors' observed hand hygiene behavior throughout the healthcare facility.

Study 3: Like most field experiments, Study 3 also has several limitations. First, the monitoring system could not distinguish between visitors, patients, or other groups of people. Therefore, it is unclear if the signs only affected visitors' dispenser usage. Obviously, it is no problem if patients and healthcare workers use the dispenser. However, some signs explicitly targeted visitors, and it is unknown what effect these messages had on the other groups of people. Second, the dispenser and signs were directed towards the hospital entrance. Therefore, the sign was not in direct view for the people leaving the lobby. The monitoring system could not distinguish between people entering and people leaving the lobby. Consequently, we could not test if the signs had a more substantial effect on people arriving versus people exiting. Third, since dispenser usage was measured as being in the immediate dispenser area, we cannot guarantee that this number is the exact figure of actual dispenser usage. However, initial sample observations showed that people in the immediate dispenser area also used the dispenser. Fourth, given the average hospitalization time per patient, most visitors should only have seen one of the seven signs, but a few visitors might have seen more. Considering that the baseline usage rate did not increase over time, we believe the potential carry-over effect is negligible. Fifth, we did not pre-test how effective the finalized signs (picture and message combined) were in activating the intended principle of persuasion. Therefore, we also do not know whether some signs might have been better at activating the principle than others. The signs should be more thoroughly pre-tested in subsequent experiments of this sort. Finally, the signs improved the dispenser usage rates only moderately. However, considering the high traffic in hospital lobbies and the potential negative consequences for every patient affected by a healthcare-associated infection (HAI), even a small increase in hand sanitation might positively impact patient safety. Having said this, we also do not know for sure whether improving visitors' hand hygiene behavior at a hospital lobby reduces HAI rates. But as already mentioned in the introduction, there is evidence pointing out that improving patients' and

visitors' hand hygiene generally reduces HAI rates. Subsequent research should examine whether there is a positive carry-over effect from the hospital lobby to on-ward behavior.

Practical Implications

Several implications for planning and designing behavior change interventions to improve patients' and visitors' hand hygiene behavior in healthcare facilities can be derived from Study 1 and Study 2. First, we saw that the three theoretical constructs of memory, attention, and decision processes; action control; and PBC were consistently identified as among the most influential determinants for patients' and visitors' but also healthcare workers' hand hygiene behavior. All three constructs are essential for self-regulation, which "refers to the extent to which people influence, modify, or control their own behavior (including thoughts and feelings) according to goals or standards" (Freund & Hennecke, 2015, p. 557). To achieve better hand hygiene behavior, knowing that self-regulatory processes are essential can be used in two ways: reducing the need for self-regulation or increasing people's ability to self-regulate.

To reduce the need for self-regulation, the environment in which people move plays a critical role. Healthcare facilities can introduce changes to the surroundings that nudge people toward cleaning their hands without thinking about it deliberately. The easiest and most important alteration is to place well-functioning hand-rub dispensers at prominent and accessible locations. Having dispensers within the field of vision and without any barriers to use them acts as a reminder and might improve people's PBC and perceived action control. Previous research has already shown that relocating dispensers can increase usage among healthcare professionals and non-professionals (e.g., Birnbach et al., 2012; Cure et al., 2014; Hobbs et al., 2016; Rashidi et al., 2016). Placing prominent signs and prompts close to hand-rub dispensers is another slightly more elaborate approach to remind people to clean their hands. Signs have the additional benefit of potentially including information on performing adequate hand hygiene and raising awareness about its importance for infection prevention. Previous research—including our findings from Study 3—has shown that this can be a practical approach to increase hand hygiene rates in hospitals (e.g., Davis, 2010; Filion et al., 2011;

Gaube et al., 2020; Grant & Hofmann, 2011; King et al., 2016; Rashidi et al., 2016). Placing technically supported, attention-grabbing visual and auditory cues on or next to the dispensers is an even more sophisticated approach to remind people to sanitize their hands. Again, some research has shown that this is an auspicious method to improve dispenser usage in healthcare facilities (e.g., Fakhry et al., 2012; Gaube et al., 2018). However, technically supported approaches come with some drawbacks: they are more expensive, require structural changes of the environment, and need maintenance. Additionally, auditory reminders add to preexisting noise pollution and alert fatigue problems and should only be employed with caution. Implementing compulsory hand hygiene programs for patients and visitors would be the most radical approach to reduce the need for self-regulation. Interventions like this imply that hospital staff directly applies sanitizer to the hands of patients and visitors at specific times of the day, e.g., before meals. While this approach has been shown to effectively reduce HAIs in several studies (Cheng et al., 2007; Gagne et al., 2010; Pokrywka et al., 2017), the downside to compulsory hand hygiene is that it requires additional human labor. Considering that healthcare workers are already scarce, compulsory hand hygiene programs are impossible for many healthcare facilities.

Interventions to increase patients' and visitors' ability to self-regulate their hand hygiene behavior are not as well researched. One previous study showed that participants who created specific hand-washing action plans and who received self-efficacy boosts through reminders about their ability to stick to these plans and their past successes significantly increased their handwashing frequency (Lhakhang et al., 2015). Research that focused on strengthening the hand hygiene-related self-efficacy/PBC of healthcare workers through rigorous training and practicing, goal setting and feedback, as well as positive role-modeling yielded promising effects (see, for example, Diefenbacher, Fliss, et al., 2019; Huis et al., 2012).

Positive role-modeling not only enhances self-efficacy/PBC, but it also sets a norm. The second major practical implication from the present research project is that behavior change intervention to improve hand hygiene behavior in hospitals should use social influence processes, especially subjective social norms. We consistently found that hospital patients and

visitors reported better hand hygiene and used the hand-rub dispenser more frequently if they saw hand hygiene as a social duty and felt that other people expected them to sanitize their hands. Consequently, interventions should be designed to make full use of the norms' powerful effect. The intervention should convey both the *injunctive norm* "I should sanitize my hands because objectively it is the right thing to do" and the *descriptive norm* "I should sanitize my hands because everybody else is also doing it" (Schultz et al., 2007). One way to communicate these norms is to use information material, signs, and reminders containing normative messages and images. When designing material for patients and visitors, it is imperative to highlight their specific roles in preventing the transmission of dangerous pathogens. Previous research—including Study 3 of this doctoral thesis—found that employing intervention material that activates social norms can increase the dispenser usage rate in healthcare facilities (Gaube et al., 2020; Gaube et al., 2018; Huis et al., 2012).

The outcomes from Study 3, in which we included all these insights to design an intervention to remind visitors about the importance of sanitizing their hands using normative messages in a natural setting, raised one additional practical implication for behavior change campaigns. Even when the intervention concept and design are grounded in solid theoretical and empirical evidence, careful pre-testing of the materials among the target group and within the target location is essential. We found that the most successful signs had the best fit between content and context. The intervention material's effectiveness can rely on a multitude of factors (e.g., relevance, trustworthiness, framing, tone, and context-fit) that must be considered.

Research Implications

Besides the suggestions for further research mentioned in the Limitations section, the present research program raised several additional research questions to be addressed in the future. First, one of the main goals of Study 1 and Study 2 was to identify the most suitable theoretical model to explain patients' and visitors' hand hygiene behavior. According to our analyses, the TDF is the most useful theoretical model of the three candidates. Now, it would be interesting to test whether an intervention solely based on the TDF findings is more effective

in improving hand hygiene behavior among patients and visitors than interventions based on the TPB or HAPA findings. Another interesting comparison would be to test the effectiveness of an intervention targeting the four most consistent facilitators and barriers to hand hygiene behavior across the three theoretical models (i.e., subjective norm, PBC, action control, and memory, attention, and decision processes) identified in Study 1 and 2 against an intervention based solely on one theoretical model.

Second, the HAPA construct planning did not mediate the association between intention and self-reported hand hygiene behavior as proposed by the theory. We had to remove the construct to achieve a good model fit. Several possible explanations for why this construct did not fit the path model are outlined in the discussion of Study 1. Besides these, we believe that theoretical models like the HAPA should account for the nature of the behavior it is supposed to explain. HAPA was developed to explain and facilitate health behavior change, with actions such as physical activity and dietary habits in mind. Behaviors like these affect people in their natural environment and on a regular if not daily basis. However, hand hygiene behavior in hospitals falls into a very different category. Most people do not regularly spend time as a patient or visitor in a healthcare facility. Additionally, hand hygiene is a highly automatized behavior that requires little deliberate thinking. Further research should be conducted to test if different theoretical models perform better in explaining and predicting different behavior types in unusual situations. Knowing which theoretical model works well for explaining different actions would help people planning behavior change interventions.

Third, the field experiment in Study 3 was designed and conducted before the COVID-19 pandemic. As already mentioned, we assume that hospital patients and visitors have become more sensitized about the importance of adequate hand hygiene due to the pandemic. Conducting an experiment like this would have been impossible during the pandemic because strict regulations have decimated the number of visitors to healthcare facilities. Also, most hospitals demanded hand sanitation from everyone entering the facility, which was often enforced by security personal. However, it would be interesting to test if the baseline dispenser

usage rate will be significantly higher after the pandemic is over and all visitation restrictions are lifted.

Finally, the most interesting subsequent research would be to plan and implement a comprehensive, multimodal hand hygiene intervention for patients and visitors, based on all the previous studies' findings. An intervention should include signs at the lobby and information material for patients and visitors throughout the facility, training for the staff to encourage hand hygiene among patients and visitors, changing the environment to enhance the accessibility of hand hygiene products, and many more. Ideally, the effectiveness of the intervention should be examined using a randomized control trial design.

Conclusion

In conclusion, the research project presented in this doctoral thesis was the first to systematically detect the determinants for hand hygiene behavior among hospital patients and visitors using three well-validated theoretical models. We then targeted the identified determinants in a cost-efficient intervention. The results showed that only observation data should be relied on when studying hand hygiene behavior among patients and visitors. We identified TDF as the most suitable theoretical model to study hand hygiene behavior among non-professionals. Considering all three models, the most critical determinants for hand hygiene behavior can be clustered into two groups: self-regulatory processes and social influence processes. The findings from Study 1 and Study 2 informed the design of Study 3, which was the first experiment to systematically compare the effectiveness of Cialdini's seven principles of persuasion on improving dispenser usage in a hospital lobby. The field experiment's results indicate that signs with the best context-fit facilitate the most substantial increase in dispenser usage. They also showed that a simple and cost-efficient intervention could be successful in a natural setting. The project can help practitioners design and evaluate interventions to improve hospital patients' and visitors' hand hygiene behavior. However, more research is needed to find optimal ways to address the facilitators and barriers to patients' and visitors' hand hygiene practice. This is crucial since we know that adequate hand hygiene reduces healthcare-associated infections and saves lives.

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