SpEYEders: Adults' and children's affective responses during immersive playful gaze interactions transforming virtual spiders

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ABSTRACT

Specific phobias like spider phobia represent a frequent mental health problem in children and adolescents, demanding innovative prevention and treatment approaches. We therefore develop an eye tracking supported Virtual Reality serious game for school-aged children, realizing gaze interactions to promote attention towards, and positive experiences during exposure to spiders. Within pilot studies in adults (n=30) and children (n=14) without fear of spiders, we assessed positive and negative affect during prototype gaze feedback through five different variants: If gazed for few seconds, the virtual spider changed into a shrunk, a rainbow coloured, or dying spider, or morphed into a smileyball, or speaks friendly. We found the highest positive affect for the rainbow and smileyball variant, followed by the shrunk and friendly speaking variant. In contrast, the dying variant was excluded due to the possible induction of negative affect. Findings indicate eligible variants for the further development of the VR serious game.

CCS CONCEPTS

• **Applied computing → Health informatics**; • **Human-centered computing → Virtual reality**; *Empirical studies in HCI*.

KEYWORDS

serious game, virtual reality, eye tracking, gaze interaction, spider phobia

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1 INTRODUCTION

The spEYEders project aims to develop a Virtual Reality (VR) serious game for the prevention and treatment of fear of spiders in school-aged children. With a 1-year prevalence of 8%, specific phobias, including spider phobia, are a frequent mental health problem in childhood and adolescence [9]. Animal phobias are the most frequently reported phobia in children and adolescents, and are associated with other mental disorders [9]. In general, the presence of anxiety disorders in childhood and adolescence increases the risk of an anxiety disorder in adulthood [5], and predicts other mental disorder [12]. The treatment approach of choice for anxiety disorders is exposure therapy [3, 22, 33]. During exposure, patients are being confronted with a feared object or situation until distress has decreased significantly. Furthermore, the violation of dysfunctional expectancies about the feared object or situation is promoted [4]. Since children usually have positive associations with game technology, serious games might offer a readily accepted platform and innovative approach for applying exposure for spider phobia in school-aged children. Within the spEYEders VR serious game, children with fear of spiders will be encouraged to confront themselves with virtual spiders, referring to the exposure rationale to treat anxiety disorders. As gaze is a measurable and modifiable aspect indicating an individual's exposure towards fear stimuli in the form of overt attention, we integrated eye tracking into the VR serious game. As a reinforcer for the children's exposure towards spiders, after gazing directly at a virtual spider, changes of the spider thought to be experienced as positive are implemented (e.g., by transformations of the appearance of the spider or by a friendly speech of the spider). These gaze-based feedback mechanisms promote experiential occupation with spiders by positive reinforcement and connect viewing spiders with unexpected, positive experiences. We deem that the way users interact with and perceive the playful VR gaze interaction elements forms a crucial component in the context of serious games dealing with anxiety disorders. Therefore, we conducted two pilot studies in adults and school-aged children without spider phobia, investigating affective reactions towards different prototype gaze interactions. In doing so, designers and researchers will be able to select feedback variants inducing positive emotions for the further development of VR serious games for spider phobic children.

2 RELATED WORK

Serious games have already been employed in the treatment of children with anxiety disorders. As some examples, the biofeedback-based game *Relax to Win* [20] is a two-player racing game in which children with anxiety problems win the race by learning to relax, and also *Mindlight* [23] incorporates neurofeedback-supported relaxation techniques and was already tested to reduce clinical anxiety symptoms in children with Autism Spectrum Disorder [32]. Also the use of VR exposure has already been proven to be safe [6], practical, and similar in efficiency to in vivo exposure in the treatment of specific phobia in adults [2, 17, 18, 31]. Also in children, first studies on VR exposure for phobias show encouraging results, e.g., for school, spider, or dog phobia [1], but those approaches did not include playful elements. Since children receiving VR exposure did not show a higher treatment motivation in comparison to in vivo exposure [21], additional gamification might imply advantages concerning the motivation to participate in exposure therapy.

Until now, only few VR-based serious games for the prevention or treatment of anxiety in children exist. As some examples, *Room VR* [25] targets bedtime anxiety, and *DEEP* is a biofeedback-supported VR game aiming at an improved anxiety regulation in children at risk for anxiety [27]. First pilot studies point toward reduced state-levels of anxiety in children after playing the game, and thus suggest its potential as an intervention for anxiety [27]. For fear of spiders, in specific, no VR-based serious game specifically tailored for children was published until now. Already employed in adults, one augmented reality (AR) game for spider phobia used a game narrative based on the Greek myth of Arachne, asking users to interact with the spider and create a bond with them to complete the game [15]. Furthermore, the Think+ VR exposure system for spider phobia integrated a playful reward system, in which users collect stars while walking across spiders [7]. Another approach transferred exposure therapy elements for spider phobia into a gamified VR application, asking users to focus on a moving spider to gain points, to keep a moving spider save by stopping objects from hitting it, or to keep focusing on an approaching spider which otherwise turns away [13, 16]. Visual attention towards the feared object was measured via a gaze-directed crosshair within this application [13]. As novelty of our approach, we integrated eye tracking-based gaze interaction into a VR serious game for children, to feedback and promote visual attention towards the feared object. What's more, we first implemented positively associated changes of spiders as feedback, which might imply further advantages in regards to expectancy violation. Research is needed to examine VR and eye tracking-based human computer interaction technology in the context of serious games for phobia prevention and treatment in children, and to explore their effects in promoting different process factors of exposure therapy.

3 METHOD

3.1 Study Design

We developed a playful gaze interaction element in VR, exposing users to a virtual spider that changes its visual appearance, transforms into another object, or speaks to the user. The feedback is realized via eye tracking technology and is triggered when the user continuously gazes at the spider (minimum dwell time as action trigger). We conducted a first pilot study in adults, and a second in children, both without spider phobia, to explore affective reactions towards different gaze-based feedback variants in healthy participants. This was achieved using a within-subjects design with different feedback variants as independent variable, and positive and negative affect as dependent variables . The results will help choosing eligible feedback variants for the further development of a VR serious game for children with fear of spiders. Only variants predominantly eliciting positive instead of negative emotions seem eligible to reinforce mental occupation with spiders, and to connect spiders to positive events in spider-fearful or phobic children. The study was conducted according to the principles expressed in the Declaration of Helsinki. All participants (and for children also the parents) received detailed information on the study and gave written informed consent. We obtained ethical and legal approval by the ethics committee at the University of Regensburg for the pilot study in children as especially vulnerable group.

3.2 Participants

For the first pilot study, we recruited 30 adult participants (18 women; age M= 24.33, SD=3.34, range: 20-33 years), all of them students with a computer science background. We only included participants without fear of spiders indicated by a prescreening score 19 within the Spider Phobia Questionnaire (SPQ) [10, 24], representing an eligible cut-off [8]. For the second pilot study, we recruited 14 school-aged children (six girls; age M=9.21, SD=1.05, range: 8–11 years) through small advertisements. We again only included participants without fear of spiders, indicated by an score of 0 within the spider phobia subitem of the Bochum Anxiety Procedure BAV 3-11 [14].

3.3 Stimuli and feedback mechanism

As a virtual spider, we used a hairy brown tarantula with approximately 20 cm in diameter. The idle animation consisted of an eight-legged walk cycle with the first and third set of legs and the second and fourth set of legs moving in synchrony, respectively. To ensure a dynamic motion, the head, thorax, and abdomen slightly swayed. To implement visual feedback mechanisms, we (a) adapted the visual appearance of the idle spider resulting in different versions. For a shrunk version, we reduced the size of the spider resulting in a diameter of approximately 10 cm. For a rainbow coloured version, we textured the spider using a multicolored diffuse map. We applied a death animation for a dying version, showing the spider falling on the back with its legs curled inward. We further (b) implemented objects the spider transforms into, specifically a smiley ball. For all variants but the dying version, the appearance changed immediately and without morphing. Only the dying version consisted of an animation of a gradual transition. We decided to mainly change the spider's appearance without an animated transition, to exclude a potential confounding variable. As further feedback variant, we (c) implemented a sound to be played in; concretely the spider speaks friendly to the participant. To implement the gaze interaction feedback mechanism, the idle spider was placed on a table in the virtual environment. To ensure that the participants focused on the spider, we used a simple virtual scene consisting of ordinary furniture like a table, a chair, and other 3D assets. The table was adjusted to the sample by different heights for adults and children. To make the virtual spider clearly visible, we used a white tablecloth resulting in a high contrast between the spider and the surroundings (see figure 1). After a dwell time of looking at the idle spider for three seconds (adult sample) or six seconds (children sample), measured via eye tracking, the system automatically changed the appearance of the spider into one out of three (adult sample) or four (children sample) variants. Each condition started with the spider's idle version with the following feedbacks variants in the adult sample: shrunk, rainbow colored, and dying (see figure 1. After an intermediate analysis of n=15 adult participants, the dying condition was taken off the task, as significantly higher levels of negative affect in comparison to both other versions were elicited in the first pilot study (see section 4). The feedback variants following the idle spider in the children sample were: shrunk, rainbow colored, smiley ball, and friendly speaking (see figure 1).

3.4 Apparatus

The virtual environment was generated by the *Source SDK* [26] based modification *VrSessionMod 0.6* [29]. We used a *HTC VIVE* head-mounted display (HMD; HTC Corporation, Taoyuan, Taiwan) with a wide horizontal field-of-view of 100° and a spatial resolution of 1080 × 1,200 pixels per eye, equipped with an integrated eye tracker continuously recording binocular gaze data with a sampling rate of 250Hz and an accuracy of 0.2° (SensoMotoric Instruments, Boston, USA). Experimental control and data recording was established using *CyberSession 5.8* [28]. The target frame rate of the applications was 90 frames per second while antialiasing was enabled. CyberSession recorded gaze data at 120 Hz and interpreted gaze data from the eye tracker with regard to the idle spider as predefined region of interest (ROIs) in the virtual environment. The gaze interaction was implemented using virtual rays colliding with the spider as our only ROI. The participants were immersed in the virtual environment and placed in front of the table perceiving the environment from a first-person perspective without having a virtual body. To avoid breaks in presence [19], we integrated the experimenters' instructions into VR by displaying the text attached on a wall as a part of the virtual environment (adults sample), or respectively integrated the rating scales into VR and gave live instructions for rating (children sample).

3.5 Measures

To assess positive and negative affect in reaction towards the feedback variants, we used the German version [11]of the *Positive and Negative Affect Schedule (PANAS)* [30] in the adult sample, calculating sum scores for positive affect and negative affect (range 10–50 each). In the child sample, we used visual rating scales for positive (joy, interest, fun) and negative affect (scare, fear, disgust) (range 0–10 each), calculating a sum score for positive and negative affect (range 0–30 each). In the children sample, we also employed an open question to access the children's experience of what they think about what made the spider change, and collected suggestions for further feedback variants.

3.6 Procedure

The study took place in our VR laboratory at the University of Regensburg. Participants completed the demographic questionnaire and the screening to exclude fear of spiders, and were given a brief introduction into VR before the task started. The participants in the real world were standing (adults) or respectively sitting on a chair (children) while being immersed into VR. The task consisted of observing the virtual spider, which appeared on the table in front of the participants. After three seconds (adults) or respectively six seconds (children) of continuously gazing at the spider, the respective visual feedback mechanism was triggered. After three seconds of presentation time for the feedback variant, the participants were teleported into a different virtual room. Here, they completed the PANAS (adults) or rated their affect on visual scales (children). The following condition again started with the idle spider. This procedure was repeated for each feedback variant (see Stimuli and feedback mechanisms), presented in the same order in all participants (adults), or in random order (children), the last to control for changes between the beginning and the end of the experiment. At the end of the VR experiment, the children additionally answered open questions.

3.7 Statistical analyses

We calculated descriptive statistics for the scores for positive and negative affect, and the item values for single positive and negative affects. Furthermore, we conducted dependent sample t-tests to compare the positive and negative affect between the feedback variants. To investigate the children's affective reactions more deeply, dependent sample t-tests comparing the level of single positive and negative items were conducted. The analyses were performed using *SPSS 26* (IBM). The alpha level was set to .050.

4 RESULTS

Within the first 15 adult participants experiencing the shrunk, rainbow coloured, and dying feedback variant (see figure 1) presented in the same order in all participants, significantly higher levels of negative affect were reported for the dying spider in comparison to both other feedback variants (see A.2). Therefore, the dying spider was excluded from the task, presenting only the shrunk and rainbow coloured variant to the further 15 adult participants. Within all 30 adult participants, positive affect was rated significantly higher for the rainbow coloured than for the shrunk spider (see figure 2, 2A and A.3). In contrast, the levels of negative affect did not differ

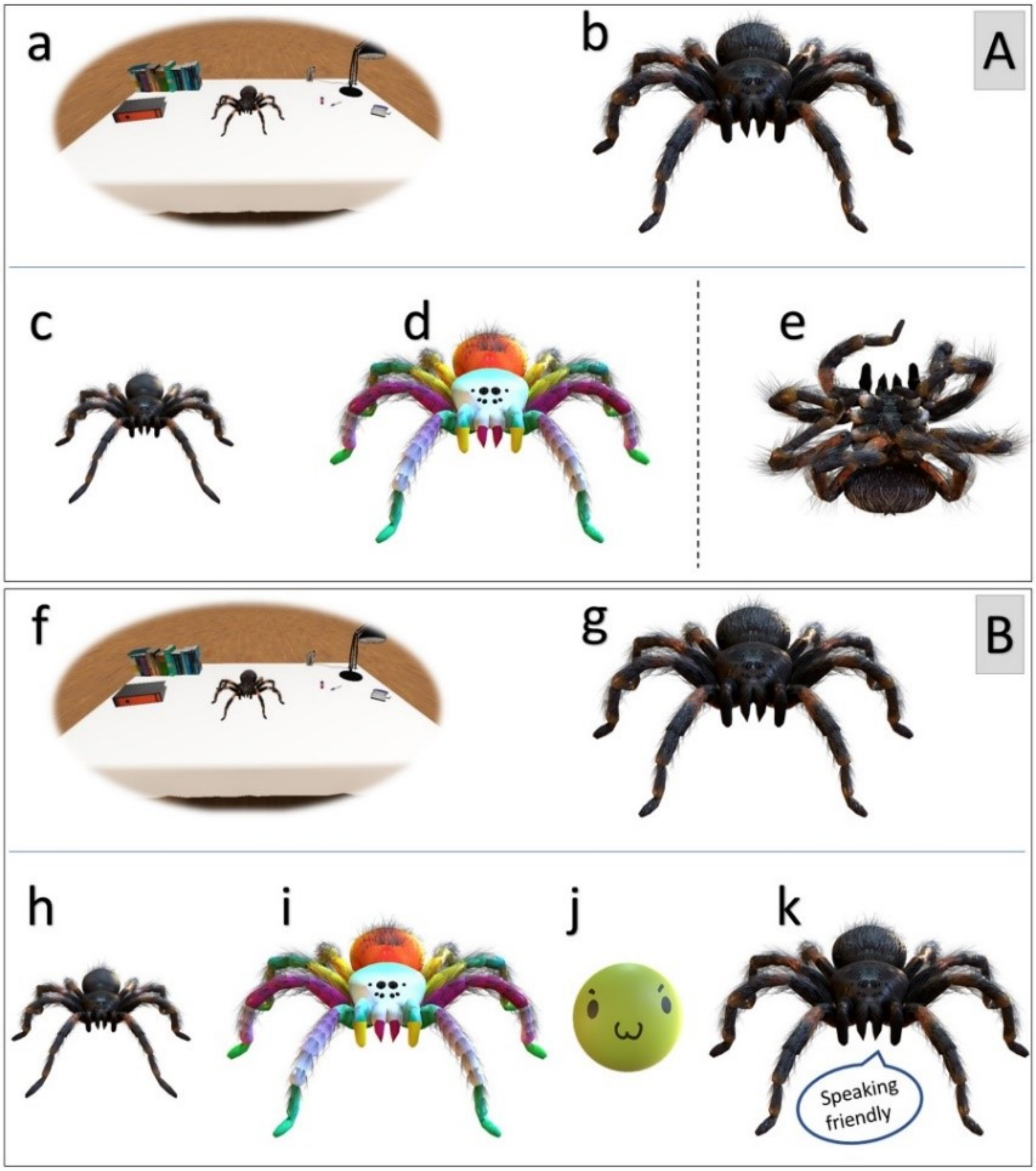

Figure 1: Idle spider and gaze interaction feedback variants for (A) adults and (B) children. Via gaze interaction mechanisms supported by eye tracking, the idle spider changes into one of the feedback variants if the user gazes it for three (adults) or six (children) seconds. a/f: Participants' point of view in VR gazing the idle spider. b/g: Idle spider. Feedback variants adults: c: shrunk. d: rainbow coloured. e: dying; excluded after being presented to n=15 adults due to the induction of negative affect. Feedback variants children: h: shrunk. i: rainbow coloured. j. smiley ball. k: friendly speaking.

significantly. Additional results for single positive and negative affects in adults are presented in A.1.

Within the 14 children experiencing the shrunk, rainbow coloured, smiley ball, and friendly speaking feedback variants (see figure 1) presented in random order, the rainbow coloured and the smiley-ball variant elicited significantly higher levels of positive affect in comparison to the shrunk and friendly speaking variant, with no significant difference between both (see figure 2, 2B and A.4). Also the shrunk and friendly speaking variant did not differ significantly concerning positive affect. Regarding single positive affects (see A.1 and A.5.1), the rainbow coloured and the smiley ball variant induced significantly more joy than the shrunk and the friendly speaking variant, and significantly more fun than the shrunk variant, with no significant difference between both. Between the other variants, and for the positive affect interest, no significant differences were found. Regarding negative affect, we found significantly higher

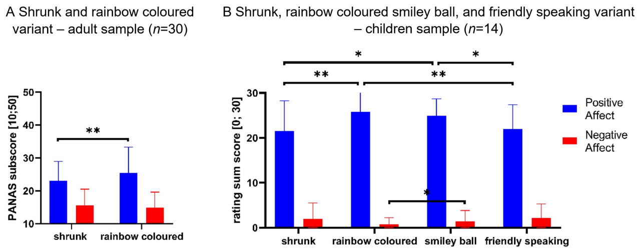

Figure 2: Positive and negative affect towards the feedback variants in the (A) adult and (B) children sample. The bars represent the mean PANAS subscores (adults), or the mean affect rating sum scores (children), the error bars the standard deviations. Significant differences within dependent sample t-tests (see A.3 and A.4): *: p<.050, and **: p<.010.

levels for the smiley ball in comparison to the rainbow coloured variant, while all other feedback variants did not differ significantly, also due to partially high standard deviations (see figure 2, 2B and A.4). Referring to the rating scores for single negative affects (see A.1 and A.5.2), this might be attributable to a descriptively higher level of scare for the smiley ball (M=0.71, SD=1.33) in comparison to the rainbow coloured variant (M=0.21, SD=0.58) (range 0–10 each), however, the difference did not reach statistical significance. In general, the mean value for negative affect induced by the smiley ball (M=1.43, SD=2.41; see A.4) was in the lower range of the scale (0–30), similar to the mean values for all other feedback variants with the friendly speaking spider showing the highest mean value (M=2.14, SD=3.16). We additionally asked about the children's experience, what they think about how the spider changed. Six children named that the computer/the program changed the spider, one child mentioned that it "just happened", one child believed that the researcher did that, and four children said that they don't know it. Furthermore, we collected the children's ideas for further feedback variants, and they suggested transformations of the neutral spider into "a spider standing on the hind legs", "a bigger spider", "an invisible spider", "other animals", "a present", "a flower", "a coffee pot", "a cat", "a snake", "a frog", "a grandpa spider", "a spider as seen from the upside".

5 DISCUSSION

Within two pilot studies, we examined the affective responses of healthy adults and children during immersive playful gaze interactions. Different transformations of a virtual spider were induced if constant attention towards it for a few seconds was measured via eye tracking. Pilot results serve as indications to choose eligible feedback variants for further developing a VR serious game for school-aged children with fear of spiders. The induction of positive but not negative emotions through different feedback variants is aspired to reinforce children's exposure to spiders. The study in adults showed that a transformation of the virtual spider into a rainbow coloured spider elicited significantly more positive emotions than a shrinking spider. Due to a high level of negative affect induced by the dying variant, it was excluded from the further usage in the development of a serious game. The rainbow coloured and shrunk variant were further examined in the following pilot study in children. The study in children showed that the rainbow coloured variant and a further introduced transformation of the virtual spider into a smiley ball both elicited significantly higher levels of positive emotions than the shrunk variant and a further implemented feedback variant of the spider to speak friendly to the child. The smiley ball variant induced significantly more substantial negative affect than the rainbow coloured variant, but the absolute values for negative affect were very low in all versions. As all variants tested in the children sample predominantly elicited positive instead of negative affects, they all can be considered for the further development and the testing of the VR serious game in children with fear of spiders. The rainbow variant and the smiley ball variant can be ranked first concerning the induction of positive emotions, the shrunk and friendly speaking feedback variant can be ranked second. However, as no child experienced that he/she induced the transformation of the spider via their gaze, the main goal for further game development will be to improve the user experience of a causal relation between the user behavior and the spider transformation. One aspect will be to implement dynamic gaze feedback, continuously responding to changes in the participants' visual attention. Furthermore, environmental contexts more relevant for fear of spiders in children (like a classroom or dark cellar), different species of spiders (e.g., endemic in the middle latitudes), and movements of the spiders as interactive elements (e.g., approaching towards the user) will be realized and evaluated in the further development of the SpEYEder VR serious game.

6 CONCLUSION

The pilot studies identified possibly eligible feedback variants for the further development of a VR serious game for the prevention and treatment of fear of spiders in children, comprising of gaze interaction elements inducing positively associated transformations of a virtual spider if measuring overt attention towards it via eye tracking, intending to promote exposure towards spiders as a reliable effect mechanism to reduce phobic fears.

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