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A psychological framework for social skill acquisition in immersive VR environments: Conceptualization, application, and empirical evaluation

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ABSTRACT

The ability to navigate complex social situations is central for human interaction. Yet, effective trainings in (psychologically) safe environments for the acquisition of widely applicable social skills remain elusive. We suggest enhancing individuals' social skills and their antecedents through virtual reality (VR) to address this gap. Our research seeks to conceptualize, apply, and empirically evaluate a novel framework for social skill acquisition in immersive environments. Using a specifically developed job-interview training, we employ a preregistered 2 × 3 mixed intervention design ($N = 114$), comparing VR-based vs. chat-based trainings across three measurement waves (before vs. immediately after vs. four months after training). Results show that our VR intervention significantly improved individuals' job-interview self-efficacy and lowered their task-related anxiety. The chat-based intervention had similarly favorable effects. The positive effects on self-efficacy and anxiety from both trainings persisted over four months. The VR training, however, required only 50% of the training time for comparable success, and participants reported a preference for the VR experience—recalling it more vividly and expressing a higher willingness to reengage in similar trainings. Mediation results align with our proposed framework for social skill acquisition in immersive environments and establish VR's effectiveness through key psychological pathways—physiological arousal, as well as cognitive and motivational factors. Our work contributes a conceptual framework to the growing body of literature on learning in VR and empirically highlights that VR trainings can provide an engaging and efficient method for training complex social behaviors in a simulated, safe, standardized, and scalable environment.

1. Introduction

The ability to navigate complex social interactions is a pivotal aspect of human life that influences individuals' well-being, relationships, and professional success (Ferris et al., 2001; Spurk et al., 2019; Tamir & Hughes, 2018). Mastering such interactions necessitates a variety of knowledge and behaviors (Howard & Gutworth, 2020; Riggio, 1986)—spanning from fundamental elements of daily interactions (e.g., eye contact, listening) to highly complex behaviors (e.g., self-presentation in job interviews and salary negotiations). In an increasingly interconnected and digitized world, the importance of effective social skills becomes more pronounced (Van Laar et al., 2017)—in our daily life, as well as in professional contexts. For example, clear and target-group oriented communication is fundamental for leaders at all levels (e.g., Deming, 2017), and cultivating sophisticated negotiation skills is central for all sales and procurement positions (e.g., Grennan, 2014).

Adequate learning environments and practicing periods are invaluable for social skill acquisition (Lehtinen, 2023), particularly in (psychologically) safe environments that allow individuals to learn with limited (to no) risks of failure. While certain professions provide tailored practice periods (e.g., medicine or teacher education) or are in itself practically driven (e.g., aviation or gastronomy), the acquirement of

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widely applicable social skills (e.g., arguing in discussions, negotiating, responding to critical questions, conveying one's viewpoints) is scarcely covered; ironically, many of these skills are assumed as a prerequisite, yet without being trained specifically.[1] Therefore, many individuals—and especially young adults in their transition from school/university to work life—are often not yet sufficiently trained to handle complex domain-unspecific social interactions (Lehtinen, 2023).

In fact, a multitude of empirical studies has demonstrated a substantial gap, characterized as a "broad mismatch" (Osmani et al., 2015, p. 6), between the skills demanded by the industry and those acquired by young individuals through their (university) education (e.g., Cox et al., 2013; Daud et al., 2011; Finch et al., 2013; Keneley & Jackling, 2011; Tran, 2015). This underscores the growing significance of employability in recent years (e.g., Baruch & Rousseau, 2019; see also Tymon, 2013)—a construct which has been defined in various ways (Cheng et al., 2022): One group of definitions conceptualize employability as a psycho-social construct (Fugate et al., 2004), which includes skills and abilities that are intended to prepare graduates for increasingly complex working environments (Chan, 2016; De Vos et al., 2011; Hogan et al., 2013; see also Taskan et al., 2022). Amongst these skills, generic (soft) skills become increasingly important (Small et al., 2018; see Treleaven & Voola, 2008, for a review).

One key commonality among these skills is their domain-unspecific nature which renders them of relevance for personal and professional development (Bridgstock, 2009). Yet, as mentioned previously, training opportunities for domain-unspecific social skill development are rare. An upcoming technology that holds promise to fill this gap is virtual reality (VR), as it enables highly realistic training experiences that are standardized, simulated, safe, and scalable (Banjo-Ogunnowo & Chisholm, 2022; Chen et al., 2020; Mayer et al., 2023; Strojny & Duzmańska-Misiarczyk, 2023).

In this paper, we seek to advance the research on social skill development in immersive environments. First, we conceptualize a framework that identifies theoretically grounded pathways and mechanisms of attaining social skills and their antecedents in virtual reality. Second, we apply this framework to a specific use case, namely a VR training of job interview skills (while openly sharing all developed materials). Third, we empirically evaluate the effectiveness of VR in comparison to a chat-based control intervention and test whether the proposed pathways of our framework hold in an applied setting. In all, we examine when, how, and why individuals can efficiently acquire social skills in an immersive VR environment.

1.1. Why should we use immersive (VR) environments to train social skills?

In the past decades, VR has developed rapidly as an innovative technology. Starting in the mid 1960s as a three-dimensional window into the virtual world—foresightedly referred to as the "ultimate display" (Sutherland, 1965, p. 507)—the concept of VR has undergone dramatic technical developments with different definitions and conceptualizations (e.g., Fuchs & Bishop, 1992; Loomis et al., 1999). Most definitions align on three features that shape today's understanding of VR: (i) immersion (i.e., an objective characteristic of a VR system; Slater, 2018; Slater et al., 2009), (ii) perception to be present in a (virtually mediated) environment (Slater & Wilbur, 1997), and (iii) interaction with the environment (see Cipresso et al., 2018). We incorporate and describe these features in the derivation of our hypotheses below.

Not surprisingly, the fast-paced development of increasingly affordable VR equipment has also attracted the interest of many researchers (Castelvecchi, 2016; Cipresso et al., 2018), with a particularly rapid increase in recent years (Silva et al., 2024). Although most research originates from computer science and engineering (>70%), the human sciences (i.e., psychology and neuroscience) follow directly behind and account for almost a fifth of extant publications (see Cipresso et al., 2018). The present research seeks to expand the field by establishing and empirically testing a theoretically grounded, psychological framework for the acquisition of social skills in VR environments (see Chen & White, 2024; Pan & Hamilton, 2018).

1.1.1. VR is invaluable to simulate realistic scenarios in a controlled setting

The potential for scholars to utilize VR in their research is immense (for meta-analyses and reviews on adjacent literatures, see Bohil et al., 2011; Coban et al., 2022; Conrad et al., 2024; Howard & Gutworth, 2020; Slater & Sanchez-Vives, 2016). Most crucially, VR has the capability to simulate highly realistic scenarios in controlled, standardized settings with minimal external confounds. For instance, social interactions are typically researched with trained actors or associates (realistic but less controlled and less scalable; Kuhlen & Brennan, 2013) or by rating videos (controlled but less realistic; e.g., Stel & Vonk, 2010). VR combines the perks of realism and control to simulate standardized scenarios that can be repeated at will and distributed across different laboratories (e.g., Hale & Hamilton, 2016).[2] VR is thus a valuable, efficient technology for both studying and fostering social skill acquisition.

Second, VR allows for the realistic simulation of hardly realizable or unusual situations. For instance, prior VR applications were used to train pilots to fly planes (Oberhauser & Dreyer, 2017), to train life-saving behaviors in dangerous settings (Zanon et al., 2014), or to reduce racial biases as participants experienced life with a different skin color (Banakou et al., 2016). Put differently, VR can be used to train and prepare individuals for situations that (a) require good performance at first try with little (to no) margin for error, (b) involve highly specific conditions, and/or (c) occur rarely (or are even impossible) in real life.

Third, VR provides a psychologically safe and controlled space for individuals to practice and refine their skills. This aspect is particularly important to consider as it allows learners to make mistakes and learn from them without anticipating real-world consequences—again fostering a supportive environment for skill acquisition in a protected space, offering insights that would have otherwise been obscured (Xu et al., 2011).

Based on these arguments, we suggest that experiencing a realistic situation in VR has beneficial effects on training outcomes in social skill acquisition. We deliberately decided to keep the term 'training outcomes' rather general, as the specific outcomes may differ depending on the context and goals; the proposed mechanisms described in the following sections, however, should remain unaffected. We derived the following hypothesis.

H1. *Experiencing a complex social situation in a realistic VR environment leads to better training results compared to a non-VR (chat-based) environment.*

To examine the effectiveness of immersive VR for social skill training, in the current case, we compared a VR-based training to a non-VR condition—implemented via a text-based chat interface. This choice was guided by both ecological and methodological considerations. Text-based chat (also referred to as 'instant messaging') is a highly prevalent mode of communication in everyday life and professional contexts (Aguado & Martínez, 2020; Dhir et al., 2020; Koch et al., 2022), making

[1] For full transparency, previous research covers social skills trainings for individuals with mental illnesses (e.g., Turner et al., 2018, for a meta-analysis), for children with intellectual or developmental abilities (Walton & Ingersoll, 2013), or individuals on the autism spectrum (Laugeson et al., 2012). However, to the best of our knowledge there are no systematically researched trainings for social skills in neurotypical individuals.

[2] In line with this reasoning, we share all the materials, videos, computer programs, code, and accompanying explanatory instructions free-of-charge via the accompanying OSF project.

it a familiar and ecologically valid comparison. At the same time, a non-VR condition represents a rigorous and conservative test: While supporting structured, turn-based, and standardized interaction like in VR, the chat-based training lacks the core affordances of VR—such as immersive cues and increased presence (see Lawson et al., 2024, for a comprehensive review of media comparison studies). Our approach thus enables a controlled investigation of whether and how immersive VR environments offer added value over a more conventional, yet interactionally rich, digital, but non-immersive format.

1.1.2. Sense of presence as a precondition for VR effects

Thus far, we primarily presented research showing VR benefits compared to conventional training methods. It is, however, imperative to also understand *why* VR yields particular effects (i.e., which underlying psychological mechanisms are at play). In accordance with other models, we propose that the central factor (and primary predictor) for beneficial VR effects is individuals' sense of 'presence' in the virtual environment (Diemer et al., 2015; Makransky & Petersen, 2021). We follow the two-dimensional conceptualization of presence by Weber et al. (2021): First, presence entails a feeling of 'being there' (Cummings & Bailenson, 2016; see also Lee, 2004; Slater, 2018). This [presence] is closely tied to immersion, which describes an objective, system-related characteristic of a VR environment (Slater et al., 2009; see also Curran, 2018) and was defined as one of the key determinants to instigate a sense of presence (Makransky & Petersen, 2021; see also IJsselsteijn & Riva, 2003). Therefore, while the concept of immersion can be objectively defined as a characteristic of a VR system, (the psychological perception of) presence is inherently subjective and contingent on individual characteristics (such as mental resources; Ling et al., 2013). Second, presence entails a feeling of 'perceived realism' in terms of the surrounding objects, their credibility and plausibility (e.g., Bailenson et al., 2006). This resembles other concepts such as a feeling of reality (Baños et al., 2000) or fidelity of the virtual space (Busselle & Bilandzic, 2008; Stoffregen et al., 2003).

Previous research has investigated the feeling of presence in different technologies (Buttussi & Chittaro, 2018; Yeo et al., 2020) and its effect in various settings: higher education (e.g., Radianti et al., 2020; see also Krassmann et al., 2023), interaction training (Uhl & Regal, 2023), surgical training (Mao et al., 2021), or psychotherapy (Bouchard et al., 2008). A sense of presence can be achieved by realistic visual features in the simulated environment but also by plausible stories and characters (Gorini et al., 2011). The experience of presence—feeling to be 'there' and perceiving the virtual space as realistic—is a crucial precondition for all subsequent, downstream mechanisms of VR (see Grassini et al., 2020). In other words, we propose that a sense of presence is the basis for subsequent VR-mediated pathways via (a) physiological, (b) cognitive, and (c) affective reactions (see Fig. 1; discussed below). We thus hypothesized.

H2. *Experiencing a complex social situation in a VR environment leads to higher perceived presence compared to a non-VR (chat-based) environment.*

1.1.3. VR elicits physiological arousal

A sense of presence in VR, in turn, elicits physiological responses (e.g., increased heart rate or reduced heart rate variability; Lemmens et al., 2022). The presentation of stimuli in VR intensifies arousal on subjective and objective physiological measures (Kuhne et al., 2023). Prior research has explored this link between presence and arousal in immersive VR environments (Choi & Noh, 2021) and found that VR elicited physiological arousal across different scenarios (Felnhofer et al., 2015) or compared to face-to-face settings (Bolinski et al., 2021). In VR-mediated therapies, for instance, presence has been referred to as a necessary condition for emotions and arousal to emerge (Diemer et al., 2015; Parsons & Rizzo, 2008; Price et al., 2011). We thus hypothesized:

H3a. *Higher presence leads to higher physiological arousal.*

This is particularly relevant for skill acquisition in VR, as physiological arousal could impact attentional and learning processes (Eysenck, 1976). For example, *high* arousal benefits cognitive skill acquisition (Homer et al., 2019) and fosters collaborative learning (Malmberg et al., 2022). However, other VR studies also provide mixed results on the impact of arousal (Jeong & Biocca, 2012) or even found that *lower* arousal leads to better performance improvements in other fields (Parong & Mayer, 2021; Prabhu et al., 2010) and in sensory studies (Radhakrishnan et al., 2023).

In the context of immersive learning, other influential research has demonstrated a so-called 'encoding-retrieval match' (Craik & Lockhart, 1972): The retrieval of learned content is improved when it takes place

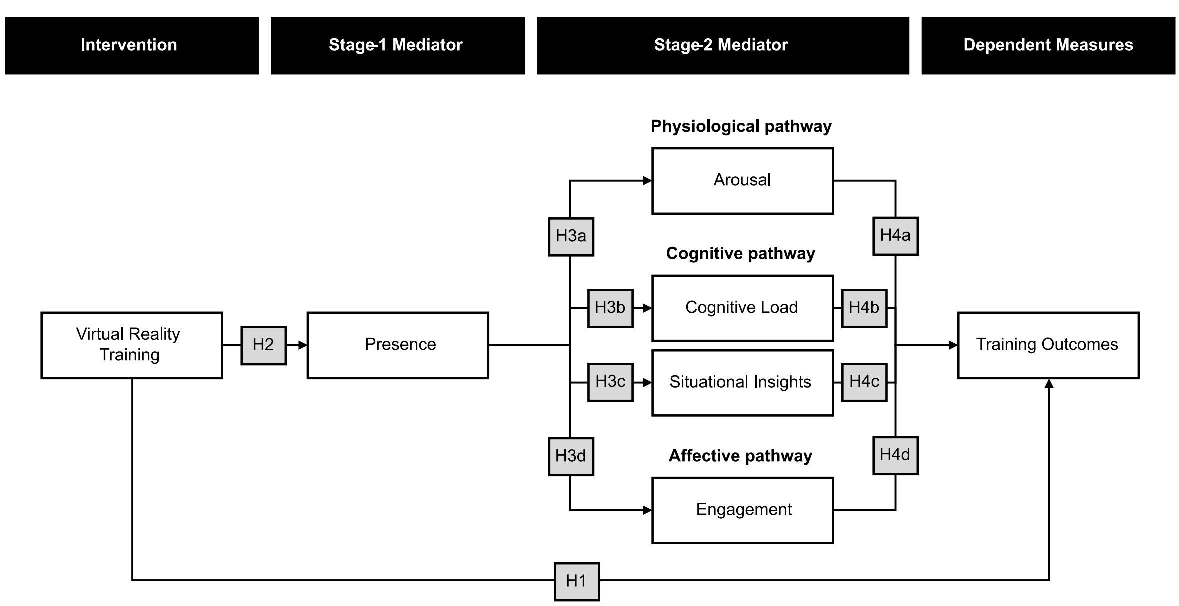

Fig. 1. Proposed Theoretical Framework for Social Skill Acquisition in VR
Note. Effective VR trainings should facilitate a sense of presence in participants (stage-1 mediator), which in turn increases their physiological arousal, cognitive load, situational insights, and engagement/motivation (stage-2 mediators). The stage-two mediators should in turn explain positive training outcomes. Grey boxes show hypotheses for the empirical evaluation of the framework in this study.

under similar conditions to its encoding. Thus, the presence-increasing VR training environment should provide similar informative (i.e., realistic) cues as the actual performance-relevant situation to maximize transfer and training effects (see Movahedi et al., 2007). Given this premise, the induced arousal and the information-rich environment in VR should lead to positive training effects in the next step (Makransky et al., 2019).

1.1.4. VR increases cognitive load and provides cognitive stimulation

We predict that a high sense of presence also increases individuals' cognitive load—defined as the mental resources needed to perform a task (Chandler & Sweller, 1991). Current theories, such as the cognitive load theory (Sweller, 2023; Sweller et al., 2011), distinguish between three additive types of cognitive load: intrinsic cognitive load (e.g., mental load resulting from cognitive processing; van Merriënboer & Sweller, 2005), extraneous cognitive load (e.g., task-unrelated elements in the [VR-]environment; Zu et al., 2020), and germane cognitive load (e.g., working memory resources devoted to learning; Sweller, 2010). In principle, all subcomponents of cognitive load are relevant for the relationship of presence and learning.

For example, (intrinsic) cognitive load is highly important for cognitive engagement due to deeper mental processing of the content (Makransky & Petersen, 2021; Moreno & Mayer, 2007). Similarly, extraneous cognitive load can have both beneficial and detrimental effects: While a task (or a virtual environment) that demands too much cognitive load can act as an (extraneous) distraction (Rupp et al., 2016; Sevcenko et al., 2021) and thus deter performance and learning (López Chávez et al., 2020; Roettl & Terlutter, 2018; Van der Land et al., 2013), an adequately designed task (or environment) should prevent overload and foster learning instead. Following the encoding-retrieval match (Goh & Lu, 2012; Nairne, 2002) and the relationship between cognitive load and performance (Babiloni, 2019), an elevated sense of presence—comparable to a real-life situation—should also lead to an adequate cognitive load, thereby facilitating successful training and boosting transfer effects. We hypothesized:

H3b. *Higher presence leads to higher cognitive load.*

In addition, we propose that VR experiences can provide valuable novel insights into unfamiliar situations (e.g., realistic first-time experiences) and facilitate learning by having individuals actively engage in this situation (Conrad et al., 2024; Makransky & Petersen, 2021). Due to its highly immersive nature, VR-enhanced presence should simultaneously result in an increased sense of agency in the situation (Jo & Park, 2023; see also Mayer, 2014). The mere presentation of content in VR can positively affect attitudes toward the content or specific activities (Tussyadiah et al., 2018; Uhm et al., 2020). This learning process—familiarizing oneself with processes, norms, and expectations in particular situations—should especially reduce anxiety and enhance feelings of comfortableness in the deliberately trained social situations. We therefore hypothesized:

H3c. *Higher presence leads to better situational insights.*

1.1.5. VR elicits emotional responses and thus fosters motivation and engagement

Just as a sense of presence triggers physiological and cognitive responses, it can also elicit emotional responses (e.g., Diemer et al., 2015; Tian et al., 2021). In turn, affective factors also determine skill acquisition in VR (Howard, 2019). For example, enjoyment and motivation positively influence the outcomes of VR interventions (e.g., Bedwell et al., 2012; Hou et al., 2012; Sitzmann, 2011). To this date, the most consistent finding from VR research—that VR is associated with increased motivation and engagement—supports this affective relationship (Jensen & Konradsen, 2018; Makransky & Lilleholt, 2018; Olmos-Raya et al., 2018). On a more general note, prior learning research underlines the importance of affective factors—with students preferring active learning (Freeman et al., 2014; Prince, 2004) and advanced skill acquisition through increased intrinsic motivation (Deci & Ryan, 2000, 2015; see also Ackerman, 1992; Kuhl, 1985). Taken together, these findings point to another explanatory pathway: An increased sense of presence should prime more motivation and engagement (Howard, 2019; Jensen & Konradsen, 2018). We hypothesized:

H3d. *Higher presence leads to higher engagement.*

Presence improves learning through physiological, cognitive, and affective pathways.

In all, a sense of elevated presence should impact physiological, cognitive, and affective pathways. We propose that, in turn, these physiological, cognitive, and affective reactions ultimately account for increased learning and training outcomes in immersive VR environments. We hypothesized:

H4. *Higher (a) physiological arousal, (b) cognitive load, (c) situational insights, and (d) engagement positively predict better training outcomes.*

1.2. A comprehensive framework of social skill training in VR

In a final step, we sought to integrate all previous predictions in a comprehensive framework of social skill acquisition in immersive (VR) environments (Fig. 1). As outlined above, the different physiological, cognitive, and affective mechanisms should jointly facilitate skill acquisition. In contrast to general models for knowledge acquisition and learning in VR (Makransky et al., 2021), we advocate for a more process-focused framework that investigates these psychological mechanisms empirically while being adaptive to different contexts and training outcomes related to social skills.

We empirically test our framework by applying it to a highly relevant and complex social scenario: job interviews. Job interviews are interactive (often dyadic) situations that are almost inevitable in people's work lives (Moscoso, 2000). They require a high level of domain-unspecific social skills, are traditionally difficult to rehearse realistically, but can be realistically implemented in an immersive VR environment. By evaluating the (long-term) effectiveness of a highly realistic VR job interview training (vs. a chat-based control training), we investigate whether the proposed relationships of our framework hold in a complex social setting.

1.3. Job interview training in VR: Scope and intended outcomes

Job interviews are amongst the most common selection procedures in organizations (Levashina et al., 2014) and have high criterion validity in predicting job performance (Huffcutt et al., 2011, 2014; Sackett et al., 2022). Job interviews are often pivotal moments in professional careers, as they require applicants to demonstrate both their qualifications and suitability for a position (Van Hooft et al., 2021). From an applied perspective, improving individuals' skills to perform well in job interviews is an important facilitator for professional development, especially for young (university) graduates entering the labor market. While interview trainings provided by university career services show promising effects (Maurer et al., 2001; Tross & Maurer, 2008), they often cannot be provided to students on a large scale (due to lack of time, space, and money). We propose that digital trainings in an immersive (VR) environment can help to overcome these obstacles, as VR allows for individualized behavioral learning in a realistic, controlled, and psychologically safe environment with evident cost- and time-efficiency.

To test our framework, we developed a VR training application for university graduates with predefined intended training outcomes. Based on prior literature, we aimed to enhance students' self-efficacy for job-interviews and to reduce their situation-related anxiety (see Huffcutt et al., 2011). We chose these constructs given they are crucial predictors for job-interview performance: Individuals' perceived interview self-efficacy *improved* their interview performance substantially[3] (Petruzziello et al., 2021a, 2021b; Tay et al., 2006; see Stajkovic & Luthans, 1998, for a meta-analysis), while high anxiety *impaired* job-interview performance (Carless & Imber, 2007). Both effects can be traced back to positive (or negative) past experiences (Hmieleski & Corbett, 2008), the opportunity (or the lack thereof) to practice (McCarthy & Goffin, 2004; McCarthy et al., 2021), and to reduced (or increased) nervousness or fear in situations with pronounced real-world implications for the applicants' professional career (Cook et al., 2000). In addition to these two core constructs, we examined two additional training outcomes: participants' interview-related self-esteem (Van Hooft et al., 2021) and their self-predicted expected performance in a real job interview.

2. Method

2.1. Preregistration

All data, analyses, and supplementary materials are publicly available on the Open Science Framework (OSF; https://osf.io/xk2gs). We preregistered the study's design, hypotheses, and analysis plan. We openly report all data exclusions, manipulations, and measures.

2.2. Participants, sample size, and power analysis

In line with our preregistered sample size analysis, our sample consisted of $N = 114$ students with the majority of students from psychology, business, and management (the main target group) at a German university ($M_{age} = 21.76$ years, $SD_{age} = 1.84$ years; 71.05% female, 27.19% male, 1.75% other). All participants were fluent in German and received either study credits or 10€ as compensation for their participation. Most participants (71.93%) had three or fewer prior experiences with real job interviews.

For the assumed, conventionally 'small-to-moderate' effect of $d = 0.35$ (Cohen, 1988), the true statistical power of our final sample was $1-\beta = 98.98\%$.

2.3. Design and process

The study followed a 2 × 3 mixed design with training condition as the between factor (VR vs. chat) and three within-participant measurement waves (before vs. immediately after vs. four months after the training). Participants were randomly assigned to one of the two training conditions (VR [$n = 58$] vs. chat [$n = 56$]).

Three days before the training, participants received study information including three job advertisements of a fictitious company (instructional material detailed below). Participants were asked to prepare for the interview with the company's HR manager, and to complete the pre-measurement questionnaire online (t_1). For both conditions, the training took place in the same neutral laboratory room. Upon completion of the training, participants were asked to complete the post-measurement in the lab (t_2). Four months after the training, participants were again contacted for the follow-up measurement (t_3). In all measurement waves, the order of the dependent variables (i.e., training outcomes) and the mediators was randomized and counterbalanced; the order of the construct-specific items was randomized within the respective blocks.

[3] This idea is largely in line with Social Cognitive Theory (Bandura, 1997, 1986), which defines self-efficacy as an individual's belief to perform successfully in a specific task—like a job interview—and to achieve desired outcomes—like convincing their counterpart, leaving a positive impression, and ultimately attaining a desired job.

2.4. Training

We first developed the training with iterative rounds of prototyping and pilot testing. For the resulting VR training, videos of a professional HR manager were displayed on a head-mounted display (Oculus Quest 2). The 360-degree videos were previously recorded with a professional actress. Participants were asked to reply verbally to the interview questions of the HR manager. Trained research assistants oversaw the progression of the interviews by selecting the next video based on participants' responses. Between the video segments, a 'fading animation' resembled a blinking moment. To ensure consistency, research assistants were thoroughly trained prior to the data collection. The interviews were semi-standardized with biographical, situational, and motivational questions (Schuler, 2018) and allowed for a maximum of two follow-up questions after each predefined question. The VR training with all materials and exemplary videos is available on OSF.

In the control condition, participants received the identical information prior to the training. Participants also received identical questions in this training version but, in contrast to the VR condition, communicated via a digitally mediated chat interface on a laptop placed in front of them. Chat-based communication (or 'instant messaging'; Dhir et al., 2020) is a highly prevalent mode of communication in personal and professional contexts (Aguado & Martínez, 2020; Koch et al., 2022; Laun & Wolff, 2025). This makes it a familiar and ecologically valid comparison, while matching the structured, turn-based, and standardized interaction. Participants received chat messages from the HR manager and replied in writing. The chat interface was a conventional instant messaging window, wherein the user's messages and those of the HR manager were displayed in a sequential, chronological order. At the bottom of the laptop screen, a text input area was designated for the participants to type in their responses. When the other person (i.e., the HR manager) was typing an answer or their next question, an animation with three dots was displayed. The questions from the HR manager were phrased identically to the VR condition (based on the underlying scripts for the videos). The same trained research assistants as in the VR condition oversaw the progression of the interview and selected the next text input of the HR manager. In summary, the two conditions differed in the medium of communication and in the type of activity (typing vs. talking). The preparation, the structure, and the training content (i.e., interview questions) were completely matched and thus allow for a rigorous and conservative media comparison (Lawson et al., 2024).

2.5. Instructional materials

Participants in both conditions received the same instructional materials three days before taking part in the training (i.e., the random assignment to the experimental condition happened only upon their arrival in the lab). The instructional materials entailed (1) three different one-page job advertisement in a fictional company, (2) a company profile for background information, and (3) instructions to choose one of the job advertisements and prepare for a 'real' job interview accordingly. The job advertisements were based on typical positions for graduates of psychology, business, and management bachelor programs (the main target group in our preregistered study). Participants were asked to choose one of the jobs according to their personal and professional interests. Unbeknownst to the participants, their selection had no influence on the training content.

2.6. Training outcomes

2.6.1. Dependent measures

We assessed participants' interview-related (1) self-efficacy, (2) anxiety, (3) self-esteem, and (4) self-rated performance prediction (7-point Likert scales; 1 = *not at all*, 7 = *very much*). First, to assess job-interview self-efficacy, we used 13 items of the *Multi-dimensional Job*

Interview Self-Efficacy Scale (MJISE; Petruzziello, Van der Heijden, de Jong, & Mariani, 2022) translated to German ($\alpha_{t1} = 0.90$; $\alpha_{t2} = 0.91$). We only included items compatible with the VR setting (e.g., "How confident are you that you could show that you are motivated to do the job?"). We excluded items that did not fit the virtual context (e.g., "How confident are you that you could find the venue of the interview?").

Second, we measured task-specific anxiety with eight items from the *Measure of Anxiety in Selection Interviews* (MASI; McCarthy & Goffin, 2004) translated to German ($\alpha_{t1} = 0.83$; $\alpha_{t2} = 0.86$). Again, we only included VR-feasible items (e.g., "My heartbeat is faster than usual during job interviews") and excluded non-compatible ones (e.g., "I worry that my handshake will not be correct").

Third, we measured self-esteem with the German version of the self-esteem scale (G-SISE, "I have high self-esteem"; Brailovskaia & Margraf, 2020).

Finally, we asked participants to predict their performance in an upcoming real-world job interview (self-reported; "How well will you perform in a real job interview?"; 0 = *not well at all* to 100 = *very well*). A full list of items is available on OSF.

In addition to our key dependent measures, we further explored potential benefits in the follow-up measurement, asking participants (a) to what extent they retrospectively thought or talked about the training in the past four months (i.e., mental rumination – 2 items; 7-point Likert scale; $\alpha = .84$), (b) whether they would recommend the training to a friend or a colleague (Dawes, 2024), and (c) how much they would be willing to pay for the training prior to their first real interview.

2.6.2. Mediators

We adapted validated scales to assess participants' sense of presence (9 items; e.g., "While I was in the virtual environment, I had a sense of 'being there'"; $\alpha = .91$; Makransky et al., 2017; Volkmann et al., 2018), physiological arousal (5 items, e.g., "In the virtual interview, I was nervous"; $\alpha = .89$; Laux et al., 1981; Spielberger et al., 1970), cognitive load (2 items, e.g., "For the virtual interview, many things need to be kept in mind simultaneously"; $\alpha = .69$; Klepsch et al., 2017), and engagement (3 items, e.g., "The virtual job interview was exciting for me"; $\alpha = .89$; adapted from Tokel & Isler, 2013). Additionally, we asked participants to assess their situational insights (4 items, e.g., "The interview showed me how a job interview works in the professional world"; $\alpha = .90$). The theoretical foundation for these additional items stems from other studies on learning in VR (e.g., Makransky & Petersen, 2021; Petersen et al., 2022).

3. Results

3.1. Randomization check

As preregistered, we conducted preliminary analyses to assess the randomization process via two-tailed Welch *t*-tests on all dependent variables measured at t_1. None of the *t*-tests reached statistical significance, $|ts| < 1.57$, $ps > .121$. Thus, we can rule out any baseline differences between both conditions that could have confounded the subsequent analyses.

3.2. Intervention benefits over time

From t_1 to t_2, results showed the predicted increases in self-efficacy ($M_{t1} = 4.74$, $SD = 0.82$ vs. $M_{t2} = 5.15$, $SD = 0.84$; $t[113] = 5.44$, $p < .001$, $d = 0.51$), predicted performance ($M_{t1} = 60.15$, $SD = 16.72$ vs. $M_{t2} = 67.20$, $SD = 16.88$; $t[113] = 4.53$, $p < .001$, $d = 0.42$), and self-esteem ($M_{t1} = 4.81$, $SD = 1.24$ vs. $M_{t2} = 5.10$, $SD = 1.25$; $t[113] = 3.94$, $p < .001$, $d = 0.37$). As expected, anxiety significantly decreased from t_1 to t_2 ($M_{t1} = 3.90$, $SD = 1.05$ vs. $M_{t2} = 3.56$, $SD = 1.16$; $t[113] = -3.99$, $p < .001$, $d = -0.37$).

3.3. Intervention differences

As preregistered, we next ran linear regression models to investigate the relationship between the experimental condition (VR vs. chat control condition) and the dependent variables measured at t_2, *while* controlling for the level of the dependent variables at t_1 (hypothesis H1; see Table 1). The condition did not predict the dependent variables at t_2 (all $ps > .233$, thus not confirming H1). At the same time, all measures showed high stability (all $r > .52$), given that t_1 measures explained considerable variance at t_2 (mean $R^2 = 41\%$; all R^2s $> 26\%$; see Table 1).

3.4. Mediation model

To analyze our proposed framework, we employed a sequential parallel mediation model to simultaneously test the underlying mechanisms (see Fig. 1). In line with our hypotheses, we included one first-stage mediator (i.e., sense of presence) and four parallel second-stage mediators (physiological arousal, cognitive load, situational insights, and engagement), whilst controlling for the levels of the dependent variables at t_1.[4] We performed the analyses using the *lavaan* package in *R* (Rosseel, 2012), with full information maximum likelihood estimation and bootstrapped 95% confidence intervals (CI) with 5,000 resamples for all effects (see Fig. 2).

In line with H2 and identical for all estimated models, the VR intervention (vs. chat control condition) significantly elevated participants' sense of presence ($\beta = 0.87$, $p < .001$). Similarly, and in line with our hypotheses, a higher sense of presence led to higher physiological arousal (H3a), higher cognitive load (H3b), more situational insights (H3c), and higher engagement (H3d; all βs ≥ 0.24, $ps \leq .006$; Fig. 2).

3.4.1. Self-efficacy

For self-efficacy, the sequential mediation model accounted for 36.9% of the variance at t_2 with significant mediation via (1) presence and then (2) situational insights and engagement (see Fig. 2A). In line with our hypotheses, we found positive effects of situational insights ($\beta = 0.27$, $SE = 0.09$, $p = .002$, 95% CI [0.10; 0.44]) and engagement ($\beta = 0.25$, $SE = 0.09$, $p = .008$, 95% CI [0.08, 0.46]) on self-efficacy at t_2. Both the total effect ($\beta = -0.09$, $SE = 0.14$, $p = .492$, 95% CI [−0.36, 0.18]) and the direct effect ($\beta = -0.24$, $SE = 0.15$, $p = .092$, 95% CI [−0.53, 0.05]) were non-significant. Self-efficacy at t_1 significantly predicted self-efficacy at t_2 ($\beta = 0.39$, $p < .001$), underlining the considerably high stability over time.

3.4.2. Anxiety

For anxiety, the sequential mediation model accounted for 51.5% of t_2 variance, with second-stage mediation via physiological arousal (Fig. 2B). Contrary to our hypothesis, we found a *positive* effect of arousal ($\beta = 0.32$, $SE = 0.10$, $p = .001$, 95% CI [0.12, 0.51]), indicating that higher physiological arousal led to more task-related anxiety after the training. The total effect ($\beta = -0.13$, $SE = 0.17$, $p = .443$, 95% CI [−0.44, 0.22]) and the direct effect ($\beta = -0.18$, $SE = 0.19$, $p = .333$, 95% CI [−0.51, 0.22]) were non-significant. Anxiety at t_1 predicted anxiety at t_2 ($\beta = 0.54$, $p < .001$).

3.4.3. Predicted performance

For predicted performance, the sequential mediation model

[4] As preregistered, we additionally measured training duration, participants' previous experience with job interviews, and research assistants rated participants' job-interview performance on three items (Bourdage et al., 2020; 7-point Likert scale; $\alpha = .92$). Robustness analyses—including training duration, previous experience, and objective performance ratings as control variables—yielded comparable results as reported in our main analyses; no changes in hypotheses support emerged (please refer to the SOM for these robustness analyses).

Table 1
Linear Regression Model for Dependent Variables at t2.

Variable	Dependent Variable							
	Self-Efficacy		Anxiety		Pred. Performance		Self-Esteem	
	M1	M2	M1	M2	M1	M2	M1	M2
Experimental Condition	−0.19	−0.19	−0.04	0.05	0.07	−0.08	−0.13	0.002
Dependent Variable at t_1		0.54***		0.67***		0.52***		0.80***
R^2	.01	.30	<.01	.45	<.01	.26	<.01	.64
$F(3, 112)$	0.99	24.22	0.05	45.16	0.13	19.81	0.47	99.65
p	.321	<.001	.825	<.001	.722	<.001	.493	<.001

Note. Experimental condition was entered in a first step (see M1 = model 1), while t_1 levels of the dependent variables were entered in a second step (see M2 = model 2). Values depict standardized beta coefficients.
***$p < .001$.

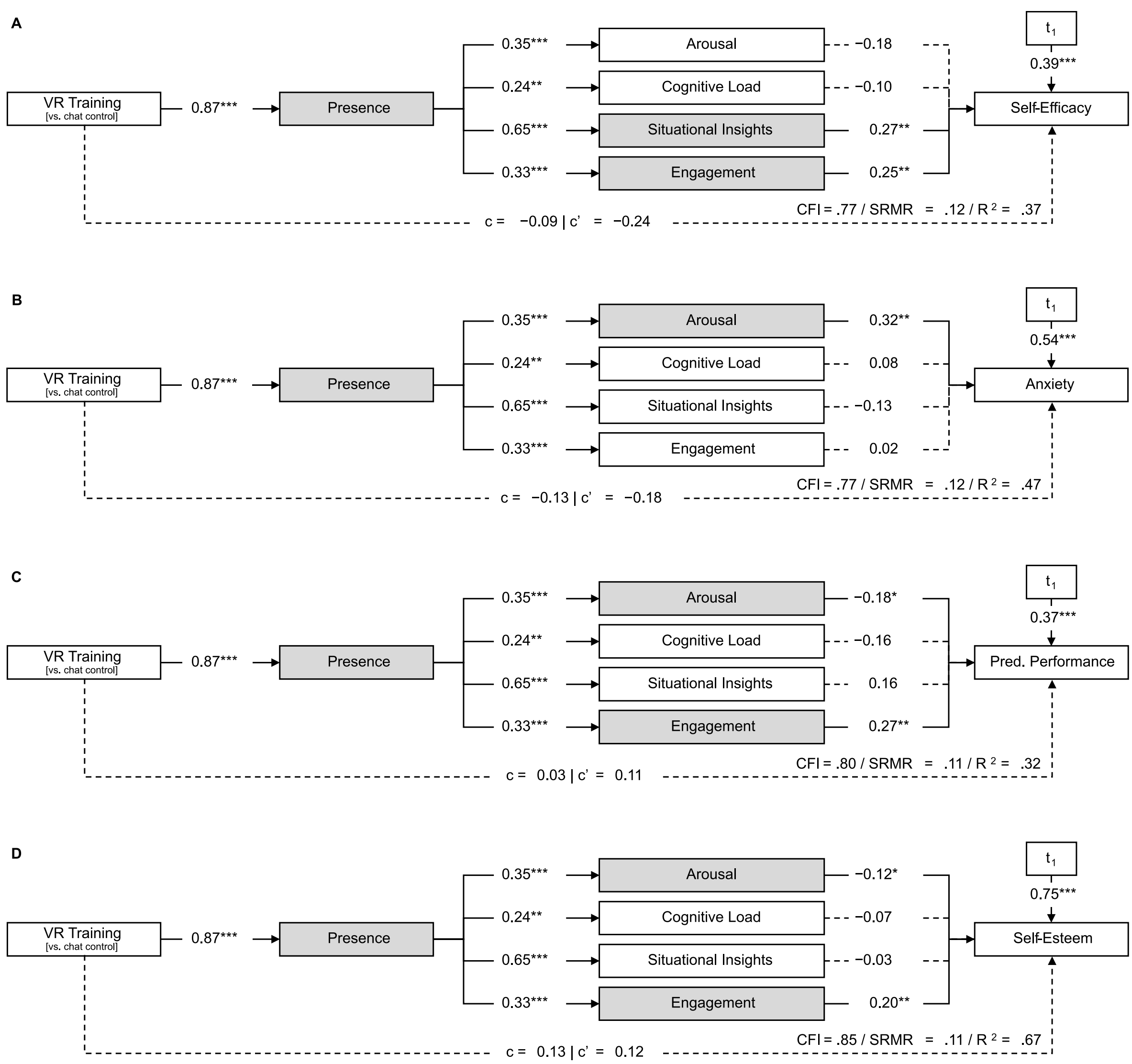

Fig. 2. Preregistered Parallel Sequential Mediation Model
Note. Mediation models summarizing the standardized effects of condition (0 = chat; 1 = VR) on self-efficacy (A), anxiety (B), predicted performance (C), and self-esteem (D), as sequentially mediated via (1) sense of presence and (2) arousal, cognitive load, situational insights, and engagement. CFI = Comparative Fit Index; SRMR = Standardized Root Mean Square Residual; R^2 = Coefficient of determination. Estimates are based on 5,000 bootstrap samples. Dashed lines indicate non-significant paths. Grey rectangles indicate significant mediation effects.
*$p < .05$, **$p < .01$, ***$p < .001$.

accounted for 32.4% of t_2 variance with second-stage mediation via arousal and engagement (Fig. 2C). In line with our hypothesis, we found a positive effect of engagement (β = 0.27, *SE* = 0.10, *p* = .005, 95% CI [0.09, 0.47]). Contrary to our hypothesis, an unexpected negative effect emerged for arousal (β = −0.18, *SE* = 0.09, *p* = .041, 95% CI [−0.35, −0.01]). The total effect (β = 0.11, *SE* = 0.15, *p* = .468, 95% CI [−0.19, 0.39]) and the direct effect (β = 0.03, SE = 0.16, *p* = .859, 95% CI [−0.29, 0.34]) were non-significant. Predicted performance at t_1 predicted self-reported performance at t_2 (β = 0.37, $p < .001$).

3.4.4. Self-esteem

Finally, for self-esteem, the sequential mediation model accounted for 66.7% of t_2 variance with second-stage mediation via arousal and engagement (Fig. 2D). In line with our hypothesis, we found a positive effect of engagement (β = 0.20, *SE* = 0.06, *p* = .001, 95% CI [0.09, 0.32]). Again, contrary to our hypothesis, a negative effect emerged for physiological arousal on self-esteem (β = −0.12, *SE* = 0.06, *p* = .040, 95% CI [−0.24, −0.01]). The total effect (β = 0.12, *SE* = 0.11, *p* = .279, 95% CI [−0.09; 0.35]) and the direct effect (β = 0.13, *SE* = 0.12, *p* = .286, 95% CI [−0.09; 0.37]) were non-significant. Self-esteem at t_1 predicted self-esteem at t_2 (β = 0.75, $p < .001$).

3.4.5. Interim mediation summary

In addition to the strong support for H3a–H3d, we also find evidence in favor of H4c (situational insights) and H4d (engagement); this support differs as a function of the training outcomes investigated. The strongest mediation support emerged for engagement, which strongly and positively affected training results for three out of four DVs (i.e., self-efficacy, performance, self-esteem). Situational insights favorably affected one outcome measure (i.e., self-efficacy). Arousal effects emerged on three of four outcome measures, albeit in the opposite direction as hypothesized in H4a (i.e., increasing anxiety, decreasing self-esteem and performance). H4b was not supported as cognitive load did not affect any of our outcome measures. In total, we found evidence for physiological (arousal), cognitive (situational insights), and affective pathways (engagement) influencing training results in this immersive VR environment. The basic reasoning of our framework thus seems warranted, although closer investigation is necessary. We return to this in the discussion.

3.5. Benefits of the VR training over the control condition

In addition to the preregistered analyses reported above, we exploratively examined short-term (i.e., training duration) and the sustained long-term training effects after four months (t_3). Participants again responded to all the training outcome measures, as well as to five novel exploratory measures (see SOM). 73.7% of the original sample participated in the data collection at t_3 ($N = 84$). Returning participants did not differ from those who dropped out in terms of relevant training outcomes at t_1 (all $|ts| \leq 1.27$, $ps \geq .209$).

First, the VR training was significantly more time-efficient (M = 25.59 min, SD = 3.38 min, range: 15–33 min) compared to the chat-based training (M = 50.54 min, SD = 7.31 min, range: 31–64 min), Welch's $t(76.83) = 23.25$, $p < .001$, $d = 4.38$, equaling a time reduction

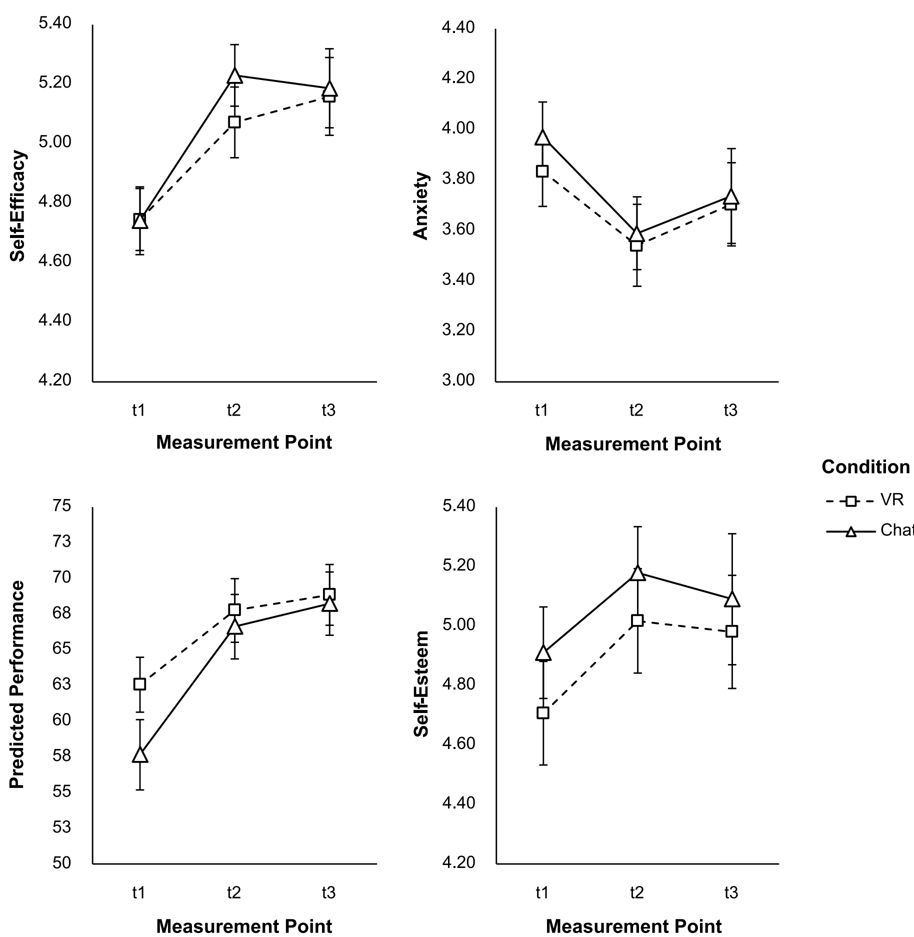

Fig. 3. Training Outcomes Across Experimental Conditions from t1 to t2 to t3
Note. Training outcomes as a function of training (VR vs. chat) and measurement wave (t_1 vs. t_2 vs. t_3). Timepoints t_1 and t_2 include the full sample ($N = 114$), while t_3 is based on all returning participants four months after the training (i.e., $N = 84$). Self-efficacy, anxiety, and self-esteem were assessed on a 7-point Likert scale from 1 to 7, predicted performance was assessed on a scale from 0 to 100. Error bars represent ±1 standard error of the mean (SEM).

of almost 50%. Second, mixed ANOVAs with condition as a between-factor and measurement points (t_1–t_3) as a within-participants factor corroborated the findings from the preregistered analyses reported above—i.e., significant improvements over time for all outcome measures, $Fs > 3.68$, $ps < .031$ (see Fig. 3; all condition main effects: $Fs < 0.70$, $ps > .404$, interaction effects: $Fs < 1.18$, $ps \geq .309$; please refer to the SOM for details).

We next examined the additional outcome measures to deepen our understanding of the long-term effects (and potential advantages) of the VR vs. the chat-based training. We conducted two-tailed Welch *t*-tests contrasting the two experimental conditions.

The results established conventionally 'moderate-to-large' (Cohen, 1988) long-term benefits of the VR training over the control condition (Fig. 4): Participants in the VR condition mentally ruminated more about the training ($M = 3.26$, $SD = 1.52$) than participants in the chat condition ($M = 2.39$, $SD = 1.28$), $t(81.95) = 2.84$, $p = .006$, $d = 0.62$. Participants were more likely to recommend the VR training to friends ($M = 7.04$, $SD = 2.52$) than the chat-based training ($M = 5.13$, $SD = 2.71$), $t(80.83) = 3.35$, $p = .001$, $d = 0.73$, and were willing to pay about 30% more for the VR training ($M =$ €19.09, $SD = 10.72$) than for the chat-based training ($M =$ €14.32, $SD = 10.00$), $t(80.75) = 2.11$, $p = .038$, $d = 0.46$ (Fig. 4).

Finally, as part of the debriefing, we informed participants that two different training programs existed—with identical content but of different format (VR vs. chat-based). We asked them which training they would more likely recommend to others (1 = *recommend chat-based training*, 4 = *recommend neither training*, 7 = *recommend VR-based training*). Despite the evident effectiveness of both trainings, participants had a clear preference for the VR-based training, $M = 6.32$ ($SD = 0.96$) with almost 90% choosing the two highest options (i.e., recommend VR over chat). The one-sample *t*-test against the scale midpoint '4' was significant, $t(83) = 22.19$, $p < .001$, $d = 2.42$, statistically supporting the preference for the VR-based training.

4. Discussion

We conceptualized, applied, and empirically evaluated a framework for social skill acquisition in immersive environments—specifically, a job-interview training in a newly-developed immersive VR (vs. non-immersive chat) environment. A high-powered, preregistered, multi-wave intervention study finds that both trainings lead to beneficial and long-lasting effects that persisted four months after the training. The VR training comes with several long-term benefits over the chat-based training in that participants mentally ruminated about it more strongly, more likely recommended it to friends (with a 90% proponent score), and were willing to pay more money for this training intervention. From a theoretical perspective, significant indirect mediation models underline the path relationships of our framework—albeit partially in the contrary direction (i.e., for physiological arousal). Overall, the mediation results show that VR increased participants' sense of presence, which affected training results via physiological, cognitive, and affective pathways. We discuss these findings and their implications in more detail below.

4.1. Short-term effects: VR as an efficient training environment

The VR training increased self-efficacy, predicted self-rated job-interview performance, and self-esteem while decreasing anxiety in a complex and highly relevant social setting (Petruzziello et al., 2021a, 2021b ; Tay et al., 2006; Tross & Maurer, 2008). Somewhat surprisingly, the chat-based training was equally effective and did not differ from the VR condition. We can think of three reasons for this pattern of results. First, the chat-based training was nearly twice as long as the VR training, which led to a longer exposure to the training content. We thus cannot completely disentangle the effects of condition and exposure duration (see Mason & Smith, 2020). The longer duration in the chat condition was partly due to participants iteratively revising their written answers before sending them (due to the asynchronous chat medium; see Swaab et al., 2012). This may well have led to a deeper processing of the training contents, which potentially compensated for the empirically decreased sense of presence.

Second, participants in both conditions prepared for and actively handled the challenging situation of a job interview. In the sense of an expectation (or placebo) effect, the mere participation in an intervention study on the topic of job interviews may have led to an unspecific training effect (e.g., Foroughi et al., 2016). Put differently, the voluntary decision to participate in the study—advertised as a job-interview training opportunity—could reflect a self-selection bias, whereby participants who are motivated to improve their employability seek out such situations more so than less motivated/interested participants (e.g., Boot et al., 2013; Green et al., 2019). Consequently, a positive expectancy effect could have led to (unintended) beneficial results, with

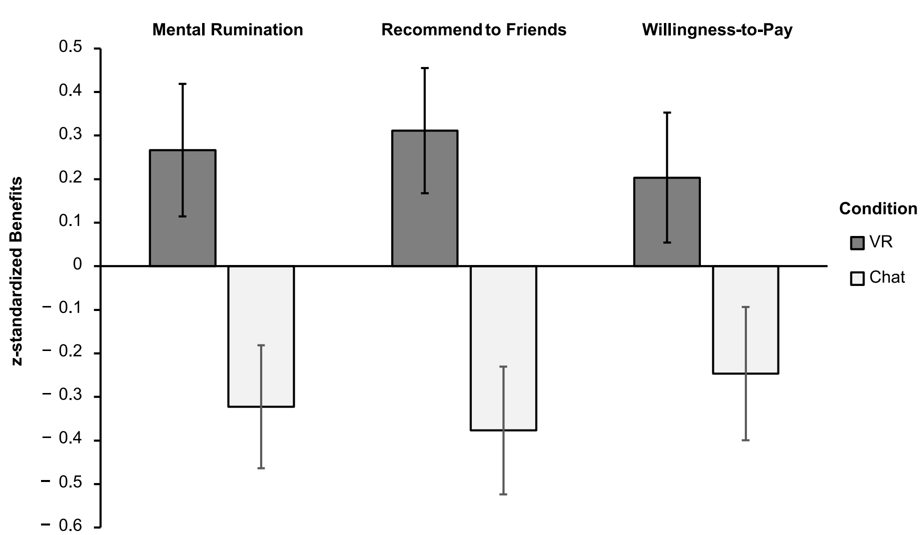

Fig. 4. Long-Term Benefits of VR Over the Chat-Based Training (4 Months Follow-Up)
Note. Four months after the training, VR participants reported higher levels of mental rumination (i.e., thinking and talking about the training; $p = .006$, $d = 0.62$), were more likely to recommend the training to friends ($p = .001$, $d = 0.73$), and willing to pay markedly more money for it than participants in the chat-based control condition ($p = .038$, $d = 0.46$). Error bars represent ±1 standard error of the mean (SEM).

participants' self-assessed skills demonstrating improvement—which may not be attributable to the training condition (see also Foroughi et al., 2016).

Third, the chat condition was a strong and conservative control condition in that it has likely put a similar level of demands on the participants as the VR training (e.g., interactivity, processing of interview-relevant questions). The two conditions only differed in medium but not at all in the otherwise matched content nor the interview questions (Lawson et al., 2024). The comparable demands over a significantly longer period may have led to comparable results (López Chávez et al., 2020; Roettl & Terlutter, 2018; Sevcenko et al., 2021). In a similar vein, the predominantly young sample presumably had a lot of experience with chat-mediated conversations with other people (or AI chat bots) from their everyday life (Aguado & Martínez, 2020; Dhir et al., 2020; Koch et al., 2022). Chatting might therefore be a highly authentic and immersive experience for them, with limited incremental benefits of an immersive training in VR. We discuss additional limitations of the chat control condition below.

In terms of training's scalability and efficiency, we should note that the VR training was considerably shorter (about 50%), thus surpassing the chat training in terms of efficiency. The provision of comparable training effects in half the time therefore makes VR especially attractive for real-life applications in which temporal resources are usually scarce.

4.2. Long-term effects: VR elicits benefits in recommendation and valuation

Beyond the immediate pre-versus-post training outcomes, both trainings also exerted long-term benefits—the effects on self-efficacy, anxiety, predicted performance, and self-esteem persisted four months later (see Fig. 3). In addition, VR also showed several long-term advantages over the chat-based training: First, VR participants mentally ruminated (i.e., thinking and talking) about the training significantly more often—suggesting they remembered the positive learning experience more clearly. Second, participants in the VR condition would more likely recommend the training to friends, were keener to go through it again themselves, and willing to spend markedly more money on participating in a similar training again. Finally, debriefed participants showed a clear preference for the VR over the chat-based training. In all, these findings suggest long-lasting subjective advantages of VR trainings for social skill acquisition.

4.3. Theoretical contribution: A framework for social skill acquisition in VR

On a theoretical level, we offer a framework for social skill acquisition in immersive environments. The empirical evidence from this study generally aligns with the conceptualized relationships of our framework: VR increases participants' sense of presence, which in turn affects training outcomes via physiological, cognitive, and affective pathways. These results call for a nuanced interpretation, however. We first focus on the significant indirect effects.

The results demonstrate substantial effects of VR (compared to chat) on presence (Grassini et al., 2020; Makransky & Petersen, 2021; Weber et al., 2021; Yeo et al., 2020). Presence consistently influenced the proposed psychological mechanisms, thereby supporting hypotheses H2 and H3a–H3d. We hence corroborate prior research that reported stable effects of immersive VR on presence and increased motivation (Bedwell et al., 2012; Howard, 2019), arousal (Malmberg et al., 2022), and cognitive load (Makransky et al., 2019; Moreno & Mayer, 2007); we extend this literature by jointly examining all psychological mechanisms simultaneously and by adding situational insights as another cognitive factor relevant in social settings (i.e., experience a real-world setting prior to the actual high-stake situation; Xu et al., 2011). Our framework thus integrates three relevant indirect pathways—arousal, cognition, affect—and establishes their mediating impact on training results.

First, VR-induced higher arousal led to increased anxiety and reduced self-esteem and predicted performance (contrary to our predictions). This points to a detrimental physiological mechanism and shows that VR needs to be applied cautiously for the training of social skills. In line with the Yerkes-Dodson law (Yerkes & Dodson, 1908), the relationship between arousal and learning is not linear, with too much arousal possibly hindering learning effects (see Diamond et al., 2007; Jeong & Biocca, 2012; Parong & Mayer, 2021; Radhakrishnan et al., 2023). This may have been the case in our training, and less challenging settings with less arousal may have more positive effects. Further research is necessary to substantiate these findings.

Second, the findings for the cognitive pathway are mixed. Participants' higher sense of presence in VR, as expected, increased their situational insights and cognitive load. While situational insights indeed coincided with higher self-efficacy, cognitive load was not linked to any training outcomes under investigation. The link between cognitive load and learning could also be non-linear, and our training may well have realized an accurate level of cognitive load, thus not systematically altering training outcomes (López Chávez et al., 2020; Rupp et al., 2016). More research on this cognitive (load) pathway is necessary to illuminate *how* and *when* respective mechanisms affect *which* type of training result. Future studies may, for instance, explore *how* cognitive load—especially intrinsic load that varies between individuals (Sweller et al., 2011; van Merriënboer & Sweller, 2005)—can be better aligned with learners' capacities through adaptive VR design (see Zahabi & Abdul Razak, 2020). Additionally, although we focused on intrinsic cognitive load, it is reasonable that presence may have also increased extraneous cognitive load, thereby possibly impeding learning effectiveness (Makransky & Petersen, 2021; Sweller, 2023). In terms of *when* these effects occur, longitudinal or repeated-exposure designs may help clarify whether learners gradually build more sophisticated mental models that reduce cognitive load over time and thus improve performance in the real-world situation (Takac et al., 2019). Finally, regarding *which* outcomes are most affected, future work should move beyond self-reported predictions to include physiological measures (e.g., heart rate or electrodermal activity; Lämsä et al., 2023), other mediating mechanisms like arousal (see above), or real-world performance indicators.

Third, via an increased sense of presence, VR led to significantly more engagement, which in turn consistently increased self-efficacy, self-reported predicted performance, and self-esteem. Combined with participants' clear preference for VR trainings at t_3, this backs the notion of VR as an affectively engaging means of learning (Jensen & Konradsen, 2018; Makransky & Lilleholt, 2018; Olmos-Raya et al., 2018) and calls for the use of VR in social skill acquisition (Freeman et al., 2014; Prince, 2004). We hope our research marks a starting point for investigating these affective mechanisms in social skill acquisition in immersive environments in more detail.

Finally, the indirect mediation effects, yet without a direct effect of VR vs. chat, warrants further discussion. The lack of direct effect is somewhat surprising, at first blush. However, it is indeed in line with recent studies on the effects of VR on psychological constructs (e.g., Loy et al., 2024). While we cannot identify the underlying reasons with certainty, a closer look at our framework pathways provides some tentative suggestions: Positive effects (e.g., situational insights, engagement) and negative effects (e.g., arousal) could have cancelled each other out (Fig. 2). In a more applied sense, just as in exposure therapy settings (Foa & Kozak, 1986), detrimental feelings of increased anxiety or decreased self-efficacy immediately after a training need to be thoroughly reflected with participants (e.g., in VR trainings) to eventually reduce the task-related anxiety (Powers & Emmelkamp, 2008).

The proposed framework also holds broad potential for a variety of other (complex) social settings. We deliberately focused on dependent variables that are domain-unspecific, yet central to professional success (Osmani et al., 2015; Tymon, 2013). This supports the assumption that similar effects of immersive training interventions should emerge in other contexts that require these social skills. For example, VR-based interventions could benefit high-stakes social interactions such as negotiations (Ding et al., 2020), where training in realistic but risk-free settings is valuable for achieving favorable outcomes (Sullivan et al., 2006). Similarly, in educational and social services, professionals like teachers or social workers need to manage emotionally challenging conversations with students or families, and immersive VR practice scenarios could well enhance interviewing skills (Huttar & BrintzenhofeSzoc, 2020; Krause et al., 2024). Finally, in specialized environments—such as legal interrogations or medical practice—VR may help bridge the theory-practice gap by offering repeatable, realistic simulations that increase procedural skills (e.g., forensic interviewing tactics or empathic and goal-oriented medical interviewing) and hence complement theoretical knowledge (see Barbe et al., 2023; Keicher et al., 2024; Neher et al., 2025). These examples underscore the broader applicability of our framework for social skill acquisition in immersive environments.

4.4. Limitations and avenues for future research

As with any research, the present study is not without limitations that reveal impetus for future research. First, we were unable to conclusively prove the superior effectiveness of our training in comparison with a conservative control condition. Nonetheless, the preregistered and exploratory analyses show that the VR training exerted convincing training effects in a time-efficient manner. Compared to a less conservative control condition like, for instance, the highly prevalent waiting control group (Steinert et al., 2017), or in a design with fixed training duration, the present effects and VR benefits would likely have been more pronounced. Moreover, while our control condition enabled a matched, structured interaction, it differed from the VR condition in terms of modality—typing in the chat-based training versus speaking in VR. This admittedly limits causal interpretations regarding which specific affordances of the VR environment were responsible for the observed effects. As recent work by Lawson et al. (2024) highlights, future research should seek to better isolate such characteristics by matching not only content but also (communicative) activities across conditions. For example, more fine-grained comparisons with 2D video trainings or with non-VR face-to-face trainings could investigate the robustness of our findings with alternative control conditions.

Second, while we find evidence for most of the indirect pathways in our framework, some mechanisms operated differently than expected (e.g., more arousal during the training leading to *in*creased job-interview anxiety). Future research should further validate our framework in different settings of social skill acquisition (see above) and also include objective assessment of targeted social skills.

Finally, although the framework assumes a multi-causal approach and covers physiological, cognitive, and affective pathways to social skill acquisition, other mediating factors might have also influenced training results. For example, the perceived fit with an actual job position, the depth of processing in VR (and chat), or other affective, motivational, and cognitive mechanisms might also explain training effectiveness (see Troll et al., 2021). Future research should identify and test additional factors to further extend the present framework.

4.5. Conclusion

We conceptualized, applied, and evaluated a novel framework for social skill acquisition in immersive environments, thereby extending prior models for general learning in VR (Makransky & Petersen, 2021). Our multi-wave intervention study reveals robust VR effects on participants' sense of presence, along with further indirect effects via diverse pathways. These pathways encompass biological markers such as physiological arousal, cognitive indicators including situational insights, and affective-motivational measures such as engagement. Applied to the case of a job interview—a complex social setting with high relevance for all individuals partaking in the labor market—VR was effective and efficient in increasing self-efficacy and reducing interview-related anxiety. While similarly beneficial effects emerged for the chat-based control condition, VR was superior in terms of efficiency and several long-term training evaluations. VR thus offers a promising and engaging means to effectively train social skills in a simulated, standardized, safe, and scalable environment, and our framework lays the foundation for further investigations of psychological pathways across a range of training interventions.

CRediT authorship contribution statement

Yannik A. Escher: Writing – review & editing, Visualization, Project administration, Formal analysis, Conceptualization, Writing – original draft, Software, Methodology, Data curation, Resources. **Hannes M. Petrowsky:** Writing – original draft, Methodology, Data curation, Writing – review & editing, Project administration, Formal analysis, Conceptualization. **Friederike Knabbe:** Conceptualization, Writing – review & editing. **Poldi Kuhl:** Methodology, Conceptualization, Writing – review & editing, Funding acquisition. **David D. Loschelder:** Writing – review & editing, Methodology, Conceptualization, Project administration, Funding acquisition, Supervision.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2025.100765.

Data availability

The authors have shared the link to all data, analyses, and supplementary materials. They are publicly available on the Open Science Framework. https://osf.io/xk2gs

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