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Exploring the Effect of Personality Traits in VR Interaction: The Emergent Role of Perspective-Taking in Task Performance

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In this work we explore the effect of personality traits on user interaction in virtual reality (VR), on the less widely studied aspect of task performance during object manipulation. We conducted an experiment measuring the performance of 39 users interacting with a virtual environment using the virtual hand metaphor to execute a simple selection and positioning task, with or without virtual obstacles. Our findings suggest concrete correlations between user personality traits and behavior data. Perspective-taking, in particular, seems to be strongly affecting task performance, highlighting the need for further research. Besides the wider implications of our results in relation to the effect of personality on how users experience VR, our main contribution lies in identifying specific traits that should be taken into account when designing experiments involving users performing such tasks. The study of these traits may also significantly advance our understanding of personality traits as part of the user model in a wider range of VR applications, including those offering personalization and recommendation functionality.

Keywords: virtual reality, VR interaction, object manipulation, task performance, personality traits, perspective-taking, user modeling

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1 INTRODUCTION

Personality, as the sum of individual differences in characteristic patterns of thinking, feeling, and behaving of a person, has been studied extensively even since the Victorian era. "Personalities are characterized in terms of traits, which are relatively enduring characteristics that influence our behavior across many situations," including, for example, introversion, friendliness, conscientiousness, etc. (Walinga, 2010). These traits are commonly measured by administering self-reporting personality tests, widely used by psychologists. They reflect people's characteristic patterns of thoughts, feelings, and behaviors (Cummings and Sanders, 2019) and are considered important as they describe stable patterns of behavior that persist for long periods of time (Caspi et al., 2005), which can affect different aspects of life (Roberts et al., 2007). Personality-targeted design has also been studied in human computer interaction (HCI) as an important factor for user modeling in a wide range of applications (Ucho et al., 2016; Eskes et al., 2016; Gunter, 2016; Jia et al., 2016; Favaretto et al., 2017; González, 2017).

The importance of personality traits as factors significantly affecting the user experience in a virtual environment (VE) has been recognized in previous research, leading to several studies attempting to explore these effects. However, such research focuses mainly on presence (Laarni et al., 2004; Alsina-Jurnet et al., 2005; Sacau et al., 2005; Weibel et al., 2009; Wallach et al., 2010; Kober and Neuper, 2013) and, to a lesser extent, on other aspects of the VR experience, such as the sense of embodiment (Jeunet et al., 2018; Dewez et al., 2019).

In this work we attempt to explore the effect of specific personality traits on a less widely studied aspect of the VR experience, namely on a user's performance when carrying out specific tasks in a VE. We argue that the implications of this underexplored area are important, taking into account that task performance experiments in the VR HCI domain are crucial in defining and assessing novel interaction paradigms. Hence, there is a need to identify those user personality traits that may have a significant effect on task performance in VR. Such traits could then be taken into account as control measures while designing a new interaction paradigm and the experiments to evaluate it; they can also be considered in the wider context of user modeling for VR applications.

We explore two categories of personality traits, namely Empathy traits (Davis, 1983) and the Five Factor Model (FFM) traits (Costa and McCrae, 1992), and their effect on task performance through a series of object manipulation tasks. Object manipulation in VR is widely used for the assessment of interaction methods (Bergström et al., 2021). Our goal is to identify whether there are any concrete correlations with certain personality traits. Our findings suggest that Perspective-taking (PT), in particular, seems to be a trait with a strong effect on task performance, highlighting the need for further research in this direction.

In the following section we introduce the background research that has informed the design of our study, focusing on two main domains: related work on interaction and object manipulation experiments in VEs as well as studies examining the effect of personality traits on the user experience in VR. **Section 3** introduces our study, presenting research questions and hypotheses, experimental setup, participants and procedure; **Section 4** outlines the results, followed by a discussion attempting to interpret our findings in **Section 5**; **Section 6** concludes the paper.

2 RELATED WORK

The objective of this work is to explore the effect of personality traits on user performance while participating in VR object manipulation experiments. This section briefly presents related work that has informed our research.

2.1 Interaction in Virtual Reality

Hand (1997) presented an early review of 3D interaction techniques separating them in three categories based on the type of task these techniques were used for: object manipulation, navigation, and application control. Additional reviews provided later by Bowman et al. (2001), Bowman et al. (2004) and updated by LaViola et al. (2017) recognized the same three task types but also identified four standard tasks for manipulation: selection, positioning, rotation, and scaling. One of the most widely used interaction metaphors in VR for performing these tasks, which several studies (Argelaguet and Andujar, 2013; Jankowski and Hachet, 2013; Hale and Stanney, 2015) have described as an effective way of interacting with objects, is the "classical" virtual hand egocentric metaphor, as described in the classification provided by Poupyrev et al. (1998). Due to the anthropometric differences between participants, the experimental environment has to be adjusted accordingly when using the virtual hand, in order to eliminate bias. One way to achieve this is using the "virtual cubit" (Poupyrev et al., 1997), which is a user-dependent measurement that derives from capturing the length of the participants' maximum reach in a virtual environment and the participants' height.

Over the years, tasks involving selecting and positioning objects in VR, also referred to as pick-and-place tasks, have been widely included in studies where participants interacted with the VE using the virtual hand technique. Some examples include comparing the virtual hand with the virtual pointer metaphor (Poupyrev et al., 1998), exploring the effects of virtual hand representation on interaction with hand tracking input (Argelaguet et al., 2016), but also comparing it with controller-based methods (Masurovsky et al., 2020), and lastly studying different visual feedback approaches for virtual grasping (Canales et al., 2019). Performance is one of the main aspects of focus in these kinds of studies, measured mainly in terms of completion time and accuracy (Bergström et al., 2021). Additionally, they identify movement data, such as the path followed by the participants' hands, as the next most—although to a much lesser extent—popular type of measurement.

In their review study, Bergström et al. (2021) formulated a set of guidelines for researchers planning object selection and manipulation studies in VR. Our study was designed and conducted before the release of their paper, and we had already applied very similar guidelines. In this work we attempt to build upon and expand these guidelines by providing useful insights on how certain personality traits may become a factor in the design and evaluation of these types of experiments, as well as underpin the analysis of their results. As the outcomes of this basic research on interaction methods in VR are then applied in different types of real-world applications to be experienced by the wider public, it is crucial to acquire a thorough understanding of the effects of personality as part of the user model on the effectiveness of the interaction methods.

In the following section we provide the background research leading to our selection of specific traits to examine in our experiment.

2.2 Personality Traits in Virtual Reality

There is extensive previous research exploring the effects of specific personality traits in VR environments, mainly focusing on the sense of presence, with studies going as far back as twenty years. Specific personality traits, measured by their corresponding self-report questionnaires, are correlated with the user-perceived sense of presence using one of the various existing self-reported presence measures. The most commonly examined personality traits in correlation with presence in VEs include: absorption (Tellegen and Atkinson, 1974), mental imagination (Sheehan, 1967), immersive tendencies (Qin et al., 2009), locus of control (Rotter, 1966), and dissociation (Bernstein and Putnam, 1986), but also empathy (Davis, 1980; Davis, 1996) and the Five Factor Model, both comprised of several personality traits.

Empathy is associated with one's emotional response to the experiences of another, the ability to adopt the perspectives of others and to see things from their point of view (Davis, 1980; Davis, 1996). Psychologist Mark Davis suggested that empathy consists of multiple dimensions, and he developed the Interpersonal Reactivity Index (IRI) to assess them (Davis, 1983). The IRI consists of four subscales:

- Fantasy Scale (FS): the ability to transpose oneself into the feelings or actions of fictional characters;
- Empathic Concern: the feeling of sympathy towards others;
- Personal Distress: the feelings of personal anxiety in difficult interpersonal settings; and
- Perspective-taking: the ability to understand the point of view of others.

The FFM, also known as the Big Five, includes five personality traits (Costa and McCrae, 1992):

- Openness to experience: creativity and imagination, curiosity and willingness to try new things;
- Conscientiousness: self-discipline;
- Extraversion: a pronounced engagement with the outside world and others;
- Agreeableness: kindness, generosity and trust; and
- Neuroticism: a tendency to experience negative emotions, such as anger or anxiety.

Several studies have examined the effect of the aforementioned personality traits, and others, on the sense of presence in a VE, with sometimes conflicting or inconclusive findings. For example, Murray et al. (2007) explore the connection between specific traits, including Absorption, with presence in an immersive VE and do not report correlation between them. Sacau et al. (2005) however, do report a significant correlation between Absorption and presence, as do Kober and Neuper (2013). Different studies (Laarni et al., 2004; Sacau et al., 2005; Alsina-Jurnet et al., 2005; Weibel et al., 2009) examine the correlation with some or all of the FFM traits with presence. Laarni et al. (2004) report a correlation between presence and Extraversion, a result not reached in other studies (Sacau et al., 2005) and (Alsina-Jurnet and Gutiérrez-Maldonado, 2010). In the case of locus of control, Murray et al. (2007) conclude that external locus of control is positively and significantly correlated with that of presence, whereas, on the contrary, Wallach et al. (2010) identify internal locus of control as a predictor for presence. Empathy has also been correlated with the sense of presence (Sas and O'Hare, 2003; Ling et al., 2013). Kober and Neuper (2013) pinpoint this correlation with the perspective-taking aspect of empathy, which seems to be comparable across different presence measures.

In their attempt to explore these conflicting results, Kober and Neuper (2013) study correlations between personality traits and different presence measures (Witmer and Singer, 1998; Usoh et al., 2000; Kizony et al., 2006) to examine whether they reveal comparable results or whether these reported correlations depend upon the used presence measure. They report that the examined personality traits showed heterogeneous correlations with the different presence questionnaires used and conclude that to find valid and meaningful relationships between personality variables and presence in VR it is beneficial to use different measures to assess presence.

The main focus on presence in previous research results partly from the assumption that the greater the degree of presence, the greater the chance that participants will behave in a virtual environment in the same or in a similar manner to an analogous real world setting (Kober and Neuper, 2013) and that a higher sense of presence can assist the transfer of knowledge acquired in the virtual environment to corresponding real-world behavior (Slater et al., 1996). However, taking into account the conflicting and inconclusive results when correlating different presence measures with personality, presence-related measures should be used with caution in experimental studies focused on personality traits and their effect on the wider VR experience.

Personality traits have also been studied lately in relation to the sense of embodiment (Shin, 2018). Jeunet et al. (2018) concluded that the feeling of agency is linked to an internal locus of control, whereas Dewez et al. (2019) report on the results of an exploratory study aiming at identifying personality traits related to the sense of embodiment towards a virtual avatar. Their findings suggest correlations between the locus of control personality trait and the sense of agency and ownership. The FFM personality traits do not seem to be the main influencing factors. However, one of the FFM traits, Neuroticism, has been correlated with the users' reaction to threat (both in embodiment questionnaires and in actual behavioral responses).

The aforementioned research results highlight the need for further exploration of personality traits in relation to the user experience in VEs. Existing studies have focused almost exclusively on the sense of presence, a self-reported measure, with, in some cases, conflicting results between different measures. In this work we turn our attention to measured task performance in VR, and initiate an attempt to determine whether and to what extent it is affected by specific user personality traits. Additionally, among the aforementioned studies examining correlations between certain personality traits and presence and embodiment, two specific results have particularly informed our work. The first is the identified correlations between presence and Empathy in general, and Perspective-taking in particular. These results have been an incentive for us to explore whether greater Empathy would allow users to in fact immerse themselves more deeply in the virtual environment, adopting the new "perspective" it brings, and whether Empathy-related traits would have a measurable impact on their task performance and behavior. Likewise, we include in our study the FFM traits and seek to identify possible correlations with task performance. As mentioned, studies have already identified correlations between Extraversion and presence, and, similarly, Neuroticism seems to affect the users' reaction to threats in a VE.

Hence, in this work, we examine the role of personality traits in VR, focusing on 1) task performance instead of presence and 2) (logged) measurements of the users' behavior and performance while performing specific object manipulation tasks in VR (logged data), instead of self-report measures. To our knowledge, there is no existing research so far examining correlations between personality traits and task performance. We consider this research the first step to more experimental studies examining other personality traits in the same context, apart from the ones we focus on in this case.

3 STUDY

The objective of this work is to focus on the possible correlations between specific personality traits and user task performance. In this section, we firstly set our specific research questions and hypotheses and then provide an overview of the experiment, the details of our study in terms of procedure and participants, and the methods and instruments used to collect data.

3.1 Research Questions and Hypotheses

Our main research questions and hypothesis revolve around the exploration of our two selected groups of personality traits, Empathy and the FFM, in relation to user performance in specific object manipulation tasks. To achieve this, we designed a VR experiment where users are asked to pick up a cube and then place it inside a hole as fast as they can, simultaneously avoiding the virtual obstacles that sometimes can be threatening (for a more detailed description see **Section 3.2**). User performance was measured using a set of logged data. We logged: 1) how the users moved their hand while performing the task, especially how high they moved it in order to avoid the obstacles, and 2) how much time they needed to complete the task, starting from the selection of the cube until its successful positioning in the hole. Further details about the logged data can be found in **Section 3.4.1**.

RQ—1 How do the Perspective-Taking and Fantasy Scale Dimensions of Empathy Relate to Task Performance?

Taking into account the positive correlation between PT and presence reported in previous work, we attempted to consider how this result would translate to task performance. Assuming that PT is positively correlated with presence, we hypothesized that users with greater PT will experience the VE with a greater sense of immersion in its "reality." In this sense, the virtual obstacles and threats while performing the tasks would seem more threatening, thus affecting their performance. We focus mainly on the Perspective-taking scale, based on the literature; additionally, we included the Fantasy scale, which also seemed relevant to the kind of greater immersion we are looking for. We opted not to examine the Personal Distress and Empathic Concern subscales as they are mostly oriented to measuring empathy towards others. We define the following hypotheses in relation to our research question:

- H1. Participants with higher PT move their hand higher.
- H2. Participants with higher PT need more time to complete the task.
- H3. Participants with higher FS move their hand higher.
- H4. Participants with higher FS need more time to complete the task.

RQ—2 How do the FFM Personality Traits Relate to Task Performance?

Previous work has identified correlations between Neuroticism and the sense of embodiment (Dewez et al., 2019) and between Extraversion and presence (Laarni et al., 2004). We define our hypotheses based on these findings, considering that traits like Neuroticism may negatively affect performance, whereas Openness to experience and Extraversion, which are more related to the sense of comfort of the user in a VE, may be positively correlated with better user performance. For completeness in exploring the FFM personality traits in relation with task performance, we explored possible correlations with the traits of Agreeableness and Conscientiousness. In the case of Agreeableness we form our hypotheses on the premise that a more positive outlook on the situation would help users fear the obstacles and threats less. In the case of Conscientiousness, we could argue that being more careful and willing to complete the task properly could make the participant avoid the obstacles and thus move their hand higher and complete the task slower.

- H5. Participants with higher Neuroticism move their hand higher.
- H6. Participants with higher Neuroticism need more time to complete the task.
- H7. Participants with higher Openness to experience move their hand higher.
- H8. Participants with higher Openness to experience need less time to complete the task.
- H9. Participants with higher Extraversion move their hand lower.
- H10. Participants with higher Extraversion need less time to complete the task.
- H11. Participants with higher Agreeableness move their hand lower.
- H12. Participants with higher Agreeableness need less time to complete the task.
- H13. Participants with higher Conscientiousness move their hand higher.
- H14. Participants with higher Conscientiousness need more time to complete the task.

3.2 Experiment Overview

To examine how personality traits may correlate with measurable user behavior data while performing object manipulation in VR, we used a typical experimental setup for this type of task (**Figure 1**). Specifically, we benefited from another experiment of ours that studied the sense of embodiment when interacting with different virtual hand representations in VR using controllers (Lougiakis et al., 2020), re-using its VE and object

FIGURE 1 | During the experiment the users perform the task of moving a cube inside a hole. (Left) Selection of the cube. (Right) Positioning inside the hole.

FIGURE 2 | The versions of the virtual hand representation that were used during the study: **(A)** Slim version, **(B)** Thick version.

manipulation mechanisms. For the purposes of the study reported in this paper, we used only one representation for the virtual hand, the realistic representation. We chose this one because our previous experiment showed that it produces a greater sense of ownership and its performance was comparable to the other options. It consists of a realistic 3D model of a human-looking hand wearing gloves, provided by SteamVR (**Figure 2**). There are two slightly different versions of hand models: a slim version and a thicker version. Hands are animated in response to button presses by the users. At the start of the experiment, users select the version they prefer.

When the experiment starts the users find themselves in an empty virtual room. They are asked to look forward, keep their body straight, and stay still, to measure their height using data from the headset. Then they are asked to bring forward their dominant hand to measure its reach and determine whether the user is left- or right-handed. This information is then used to adjust accordingly the height and the length of a square virtual table that appears in front of them, as well as the position of a hole on the side of the table (left or right, depending on the individual user's handedness). Nine cubes are also evenly spread on top of the table, creating a 3 × 3 grid with the possible target objects for the task.

The users' task is to select the cube and then position it inside the hole as fast as they can (**Figure 3**). The first step to do this is to push a green virtual button that is in front of the table using their virtual hand, thus marking the beginning of the selection part of the task (**Figure 3A**). Then, one of the nine transparent cubes becomes non-transparent to indicate that this is the currently active target (**Figure 3B**). The users approach the cube with their virtual hand. The moment they touch it, it gets highlighted and that means it can be grabbed by pressing the trigger button (**Figure 3C**). The cube is then attached to their virtual hand until it is positioned inside the hole; it cannot be dropped accidentally or intentionally (**Figure 3D**). The hole has almost the same shape as the cube, so accuracy is required to place the cube in (**Figure 3E**). In this way, information about accuracy is inferred by the duration of the positioning task. When it is placed correctly, the cube falls inside (**Figure 3F**), and then all the transparent cubes appear again so that the task can be repeated (**Figure 3G**), until all of the nine cubes have been selected exactly once.

The user is presented with four conditions, three with obstacles and one without an obstacle. The four conditions were selected based on two properties: if they are threatening or not and if they are solid or not. The four conditions are:

- the None obstacle condition (**Figure 3**), which is neither threatening nor solid;
- the Brick Wall obstacle condition (**Figure 4A**), which is solid but not threatening;

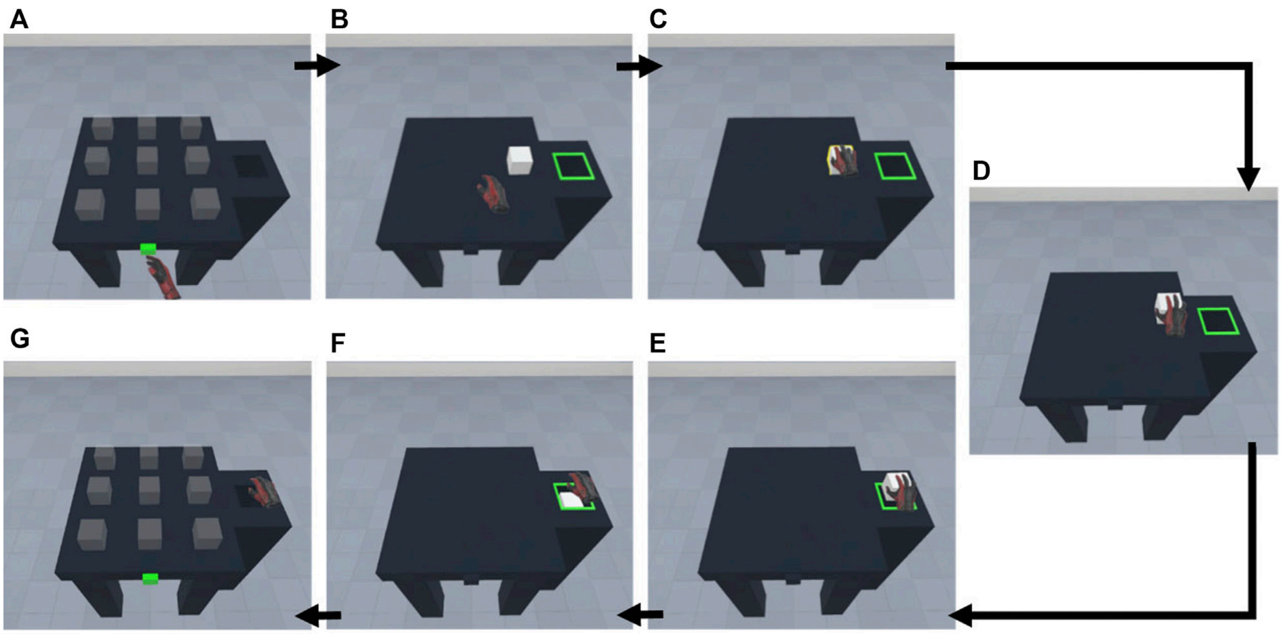

FIGURE 3 | The steps to completing a task: clockwise from **(A)** pushing the button, **(B)** viewing active cube, **(C)** grabbing cube, **(D)** moving attached cube, **(E)** aligning cube to hole, **(F)** dropping cube in hole, and **(G)** viewing all cubes to restart.

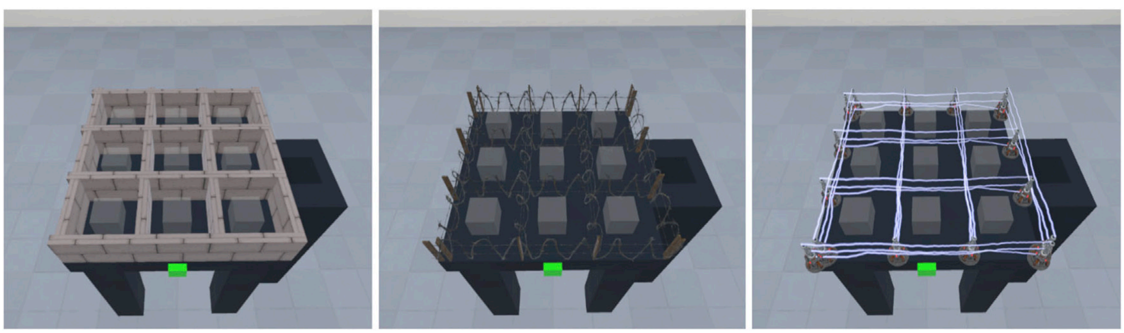

FIGURE 4 | Virtual obstacles that appear on the table during the tasks: from left to right **(A)** Brick Wall obstacle, **(B)** Barbed Wire obstacle, **(C)** Electric Current obstacle.

- the Barbed Wire obstacle condition (**Figure 4B**), which is both threatening and solid; and
- the Electric Current obstacle condition (**Figure 4C**), which is threatening but not solid.

The participants repeat the task 108 times through three sessions of the four obstacle conditions (three obstacles and no obstacle), and nine cube positions. At the outset, the participants practice the task without an obstacle for four random and distinct cubes. This gives them the opportunity to become familiar with the interaction mechanics as well as the whole process before starting with the main part of the experiment. Each of the three sessions that follow contain four blocks of task repetition, one for every obstacle condition. In each block, the task is repeated nine times, one for every cube position, until all the cubes have been selected exactly once. To avoid any ordering effects, the obstacle conditions and the target cube positions are presented in random order.

3.3 Participants and Procedure

Participants were recruited through an open invitation and were scheduled on different days and times using an online scheduling tool. A total of 39 people participated in the experiment, 22 of whom identified themselves as women and 17 as men, ranging from 21 to 63 years old. They had varied levels of experience in terms of how many times they had used VR: no experience at all (12 participants); 1–3 times (18 participants); 4–10 times (7 participants); and 10 + times (2 participants). Three of the 39 participants reported their left hand as the dominant hand. Our institutional ethics review committee approved the study and we followed all standard processes.

The total duration of the experiment was on average 55 min, and consisted of three parts:

1) In the first part, which lasted 15 min on average, the participant was welcomed by a member of our team. During this part, we briefly introduced the experiment, making sure they were aware of what to expect, including the possible risks associated with the use of a VR system. Additionally, we provided the participant with a sheet containing more information about the experiment, detailing also the type of data recorded (logs, photos, audio and video), and a consent form. Upon obtaining consent, we helped the participant wear and become familiar with the VR apparatus.

2) After that, the experimenter loaded the application and the second part of the procedure started, which lasted 25 min on average. At first, the participant, following the instructions of the experimenter, went through a calibration phase that measured the participant's height and the length of their arm's reach through the VR equipment. This information was used to adjust the size of the virtual table, specifically the length and width of the surface and the height of the legs, according to the biometric characteristics of the participant. The purpose of this calibration was to obtain cleaner experimental data, unaffected by the physical differences between participants. Additionally, gender, dominant hand, and previous experience in using VR were stated by the participant. Then, the main phase of the experiment started, which contained the three different sessions of repeating tasks, as described in **Section 3.2**. The end of the second part of the procedure was marked when all the tasks for the three sessions had been completed.

3) Finally, for the third part of the experiment, which lasted 15 min on average, the experimenter helped the participant remove the VR headset. The participants were then asked to fill in the personality traits questionnaire described in **Section 3.4.2**.

The Unity 3D game engine was used to develop the virtual environment for the experiment. The application ran on a Windows 10 desktop PC that met the recommended technical requirements, with an HTC Vive VR system connected to it.

3.4 Methods

3.4.1 Collected Data

To support the analysis of user performance in object manipulation tasks, we defined a set of data that were logged during the experiment. This aimed to record the characteristics of the participant's hand movement while performing the task, as well as the duration of this task. As previously mentioned, each task instance performed by the participants combined an object selection task where they had to grab the object from the table grid, and an object positioning task, where they had to place the object they had grabbed in the hole.

For each task, we recorded the positions of the complete path of the hand while performing it. We then calculated from the hand movement data two metrics:

- Maximum hand height, as the highest point of the participant's hand movement relative to the table during the task
- Average hand height, as the average height of the points the participant's hand reached relative to the table during the task

We selected these two metrics to examine how much the participants were trying to avoid the obstacles, by moving their hands higher so that their virtual hand or the cubes they were moving would not get in contact with them while performing the task.

For each task we also recorded the start and end time, as well as the time the selection part was completed and the positioning part began. From these, we calculated the selection, positioning, and total duration of the task, recorded in milliseconds:

- Selection duration, as the time the user needed to grab the object after they pressed the green button and the target cube was determined
- Positioning duration, as the time the user needed to move the object they grabbed to the hole
- Total duration, as the sum of the aforementioned durations

For the needs of our experiment we logged the data describing the hand movement and task duration taking also into account the four obstacle conditions (Brick Wall, Electric Current, Barbed Wire, and None). To this end, we defined 10 variables related to hand height (maximum and average hand height for each of the four obstacle conditions, plus the task total) and 15 variables related to task duration (selection, positioning, and total task duration for each of the four obstacle conditions, plus the task total).

3.4.2 Questionnaires

To record the participants' personality traits for the purposes of this experiment, we used the relevant questionnaires for both the IRI (Davis, 1983) and the FFM (Costa and McCrae, 1992) (see **Section 2.2**). A concern was to avoid overloading the users with long questionnaires, so for the IRI we kept only the statements pertaining to the Perspective-taking and Fantasy Scale personality traits that we examined in this work. The questionnaires were presented to each user to fill in individually in Google Forms (see **Supplementary Material**).

For the Empathy-related personality traits, the PT and FS subscales of the IRI each consist of a set of seven statements on a 5-point Likert scale. The IRI contains both positive and negative statements. For each of the two subscales, a score is calculated. The total score is then counted by adding up the positive and negative scores. An example statement for Perspective-taking is "I sometimes try to understand my friends better by imagining how things look from their perspective."

For the FFM, we used the short version presented and adopted also by Antoniou (2019). This comprises a set of 15 pairs of statements, three for each of the five personality traits (Neuroticism, Extraversion, Openness to experience, Conscientiousness, and Agreeableness). An example of such a pair, for Openness to experience would be "I am creative, I like to come up with new ideas" and "I am focused on more practical tasks and solutions." For each pair, the users are called to select the statement that they identify with the most.

TABLE 1 | RQ1 related hypotheses results summary: Exploring the correlation between PT and FS and logged data.

Hypotheses	Results
H1. Participants with higher PT move their hand higher	Rejected—The analysis revealed that PT is negatively correlated with higher hand movement (for all 10 variables of average and maximum hand height)—**Table 2**
H2. Participants with higher PT need more time to complete the task	Rejected—The analysis revealed that PT is negatively correlated with the task completion time (for total and selection task duration—8 out of 15 variables)—**Table 3**
H3. Participants with higher FS move their hand higher	Rejected
H4. Participants with higher FS need more time to complete the task	Rejected—The analysis revealed that FS is negatively correlated with the total (Pearson = −0.350, p = 0.029) and selection task completion time (r = −0.350, p = 0.029) for the None obstacle condition

TABLE 2 | PT is negatively correlated with higher hand movements (higher maximum and average hand height).

Hand height related data	PT
Maximum Hand Height	r = −0.481, p = 0.002
Maximum Hand Height—Brick Wall	r = −0.483, p = 0.002
Maximum Hand Height—Electric Current	r = −0.466, p = 0.003
Maximum Hand Height—Barbed Wire	r = −0.422, p = 0.008
Maximum Hand Height—None	r = −0.375, p = 0.019
Average Hand Height	r = −0.432, p = 0.006
Average Hand Height—Brick Wall	r = −0.443, p = 0.005
Average Hand Height—Electric Current	r = −0.321, p = 0.046
Average Hand Height—Barbed Wire	r = −0.425, p = 0.007
Average Hand Height—None	r = −0.374, p = 0.019

TABLE 3 | PT is negatively correlated with the task completion time.

Duration related data	PT
Total task duration	r = −0.379, p = 0.017
Total task duration—Brick Wall	r = −0.335, p = 0.037
Total task duration—Electric Current	r = −0.473, p = 0.002
Selection duration	r = −0.452, p = 0.004
Selection duration—Brick Wall	r = −0.404, p = 0.011
Selection duration—Electric Current	r = −0.487, p = 0.002
Selection duration—Barbed Wire	r = −0.406, p = 0.010
Selection duration—None	r = −0.373, p = 0.019

4 RESULTS

For the analysis, the participants' logged data were handled as continuous variables, making no assumption about their distribution. These variables include the 15 duration-related and the 10 hand height-related variables, as described in **Section 3.4.1**.

Thus, we calculated the bivariate correlation coefficients of each personality trait variable with logged data variables using the Pearson correlation coefficient (Pearson's r), in SPSS. The control rejects the "No correlation" hypothesis with a significance level of $p = 5\%$ when the p-value of the sample is less than 0.05. The value of the Pearson rank correlation (indicated with r in this section) shows whether the variables are proportional (0,1] or inversely proportional [−1,0).

To rule out any possible effect of the participants' experience with immersive VR environments on their performance, we examined its correlation to the logged user data. No significant correlations were found, confirming that experience in VR has not been a factor in this experiment.

In the remainder of the section we present the results of the analysis following our hypotheses presented in **Section 3.1**.

4.1 Empathy Perspective-Taking and Fantasy Scale and Task Performance

The results of the study revealed interesting findings in relation to RQ1, which considers the correlation between the PT and FS subscales and task performance. All four of our hypotheses in relation to PT and FS have been rejected. Surprisingly, to a great extent in the case of PT and to a much lesser extent for FS, we noticed that there were indeed correlations with task performance, but the opposite of what we had expected: participants with higher PT, instead of being more affected by the obstacles—and thus performing worse in the tasks—actually seemed to perform better than those with lower PT.

Table 1 summarizes the findings for RQ1. **Tables 2**, **3** summarize the statistical analysis results for PT and its correlation to hand height (**Figure 5**) and task duration (**Figure 6**), respectively. In **Table 2** we note that there is strong negative correlation between Perspective-taking and both maximum and average hand height, for the average of all tasks as well as per obstacle.

Similarly, in the case of task duration, we notice that the results confirm the correlation of PT with the average selection duration per obstacles, without obstacle and in total. Correlations are also detected for the average total task duration, for the Brick Wall obstacle, the Electric Current obstacle, and in total. Interestingly, no correlations have been observed for the positioning duration. As it can be seen in **Figure 6**, there is a reduction in the average time for users with greater PT. This is more pronounced and significant for the total and selection times.

A visualization of these hand movements, as they were performed by the participants to grab the cube positioned in the middle of the table, can be seen in **Figure 7** for all the obstacles. They are divided into three differently colored groups, according to their PT score (0–3 Low, 4–6 Medium, 7–9 High).

In the case of FS, the results are far weaker. No correlations, positive or negative, have been detected with the maximum and average hand height. Only for the task duration, total and selection, a negative correlation was observed for the None obstacle case.

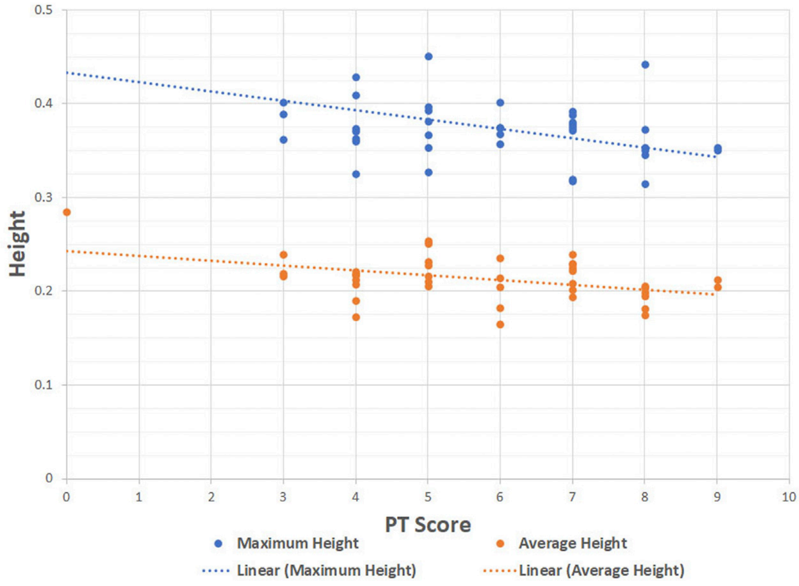

FIGURE 5 | Maximum and average height of hand movement per task, by PT rating.

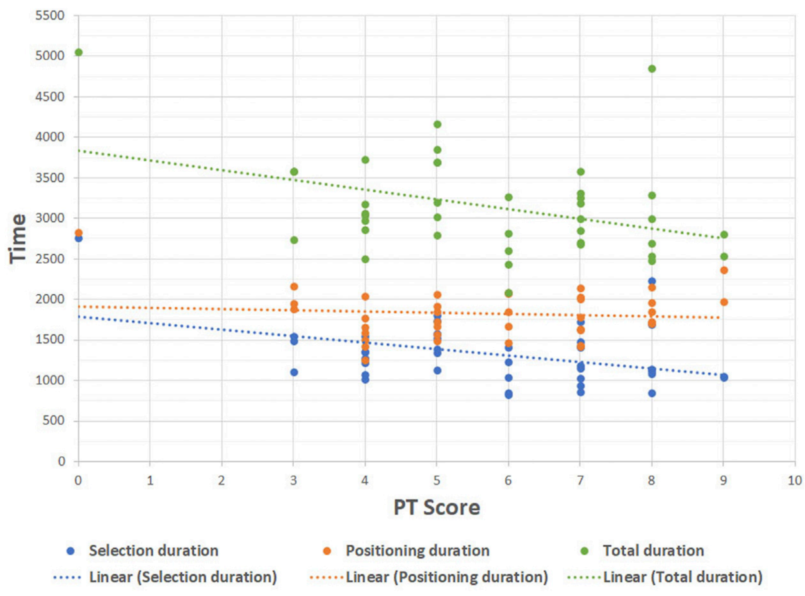

FIGURE 6 | Average task selection, positioning and total time, by PT rating.

In the case of H4, only the None obstacle case revealed a negative correlation with FS for the task total and selection duration. For the rest of the obstacles no correlation was detected. Only in the case of the Brick obstacle, there is negative correlation, however its significance is above 0.05 (p = 0.073 for total duration and p = 0.051 for the selection duration). Although this result should not be strongly taken into account, it can be considered suggestive of a weak correlation between FS and the selection and total task duration only when no threatening obstacles are present. In the case of threatening obstacles like the Barbed Wire and Electric Current this correlation is not evident, probably being affected by other, stronger factors.

In the case of the None obstacle condition and the Barbed Wire obstacle, the correlation of PT and total task duration (**Table 3**) is negative, as is the case for the other two obstacles.

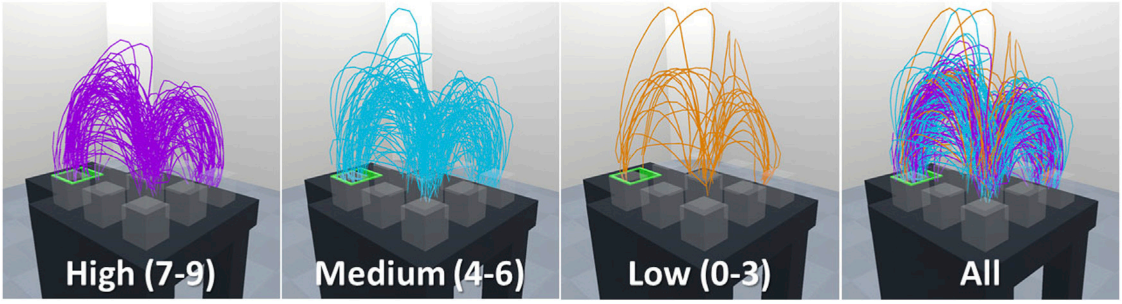

FIGURE 7 | Visualization of the users' hand movement while performing the task grouped by PT score.

TABLE 4 | RQ2 related hypotheses results: Exploring the correlation between the Neuroticism trait and logged data.

Hypotheses	Results
H5. Participants with higher Neuroticism move their hand higher	Rejected
H6. Participants with higher Neuroticism need more time to complete the task	Partly confirmed—For 3 out of 15 variables: Positioning duration (Pearson = 0.335, p = 0.037) Positioning duration—Barbed Wire (Pearson = 0.436, p = 0.005) Task duration - Barbed Wire (Pearson = 0.326, p = 0.043)

TABLE 5 | RQ2 related hypotheses results: Exploring the correlation between the Openness, Extraversion, Conscientiousness, Agreeableness traits and logged data.

Hypotheses	Results
H7. Participants with higher Openness to experience move their hand lower	Rejected
H8. Participants with higher Openness to experience need less time to complete the task	Partly confirmed—For 4 out of 15 variables: Selection duration—Brick Wall (r = −0.350, p = 0.029), Positioning duration—Electric Current (r = −0.356, p = 0.026), Task duration—Brick Wall (r = −0.322, p = 0.045), Task duration—Electric Current (r = −0.355, p = 0.026)
H9. Participants with higher Extraversion move their hand lower	Rejected
H10. Participants with higher Extraversion need less time to complete the task	Rejected
H11. Participants with higher Agreeableness move their hand lower	Rejected
H12. Participants with higher Agreeableness need less time to complete the task	Rejected
H13. Participants with higher Conscientiousness move their hand higher	Rejected
H14. Participants with higher Conscientiousness need more time to complete the task	Rejected

However the significance is in both cases greater than 0.05 (p = 0.09 for None and p = 0.075 for the Barbed Wire). Although these results cannot be taken into account as statistically significant, they are suggestive of a correlation between total task duration and PT which is not affected by the type of obstacle.

4.2 The FFM and Task Performance

The results of the study partly confirmed our hypotheses defined in the context of RQ2 exploring the correlation between the FFM traits and task performance. **Tables 4**, **5** summarize the results.

Interestingly, Neuroticism seems to be positively correlated with the positioning time, for the all tasks average and the Barbed Wire obstacle in particular (H6). For the Brick Wall and None, a correlation is detected, however the significance is above 0.05 (p = 0.078 for brick and p = 0.075 for None) and it could be considered only indicative of a correlation. In the case of Electric Current, this, even marginal correlation, is not detected. So in the case of Neuroticism there seems to be an indication for a correlation with the positioning duration where the role of the obstacles can be considered inconclusive.

Openness to experience was negatively correlated in some cases with selection, positioning, and total task duration for specific obstacles (Brick Wall for total and selection, and Electric Current for total and positioning), thus partly confirming our initial hypotheses. Specifically for selection duration, an indication for correlation with significance above 0.05 has been detected for the Electric Current (p = 0.074) and None (p = 0.073). This is the case also with the total task selection duration (p = 0.059).

We have not detected any correlation between the Extraversion, Conscientiousness, and Agreeableness traits in our task performance data.

5 DISCUSSION

In this work we set out to explore how specific personality traits may affect task performance in object manipulation, in particular the selection and positioning tasks, where obstacles and virtual threats are present. Having no prior research in exactly this context to rely on, we attempted to build our hypotheses on previous research outcomes on the sense of presence and embodiment. In the case of the FFM personality traits and RQ2, our results may not be decisive but they are indeed indicative of a relation between task performance and the traits of Openness to experience and Neuroticism. For these traits, correlations have been detected with task duration. In particular, participants with higher Openness to experience exhibited significantly shorter task duration for the Barbed Wire and Electric Current obstacles. Conversely, participants with higher Neuroticism exhibited significantly greater positioning task duration and specifically for the Barbed Wire, positioning, and overall task duration.

This fact may be explained by the relevance of the FFM traits with the levels of stress and anxiety the user might be experiencing in the virtual environment. There is a significant body of research examining stress in VR, mostly from the perspective of using this medium to treat different types of anxiety disorders, such as music performance anxiety (Bissonnette et al., 2016), or simply to train users to improve stress response in live training exercises (Lackey et al., 2016). The relation between the FFM personality traits has also been explored in relation to stress from the perspective of psychology (Uliaszek et al., 2010). To this end, we consider it worth noting that the detected correlations with the FFM traits were relevant to task duration in tasks where obstacles and threats were present, possibly affecting the participant's levels of anxiety.

These results are indeed interesting and merit further investigation in the specific context of an experimental setup. However, the fact that the identified correlations (only with certain aspects of task duration and not with the height of the hand movement) were not extensive enough implies that these personality traits are not necessarily crucial to consider as control measures while setting up an experiment related to object manipulation task performance.

In the case of the Empathy-related trait FS we reached a similar conclusion: indications are evident for a certain effect of this trait on task performance. Interestingly, in contrast with the results for Neuroticism and Openness to experience, in the case of FS, the correlations were not detected in tasks where obstacles were present. Only in the case where no obstacle was present, participants with higher FS exhibited significantly lower task duration. Although these results merit further investigation, they cannot at this moment be considered conclusive enough to become a concern for planning, participant selection, and result analysis in similar experiments.

However, the fact that these personality traits affect the two task types, selection and positioning, in different ways, also in relation to the presence and type of obstacles, indicates that the effect of these personality traits may be stronger in other variations of our experimental set-up. Neuroticism seems to have a concrete effect on the positioning task. This is not the case with PT and FS, the effect of which may be more evident in the selection task. The fact that the role of obstacles is stronger during the selection phase, points to the need to further explore FS and PT and their concrete role in object manipulation of tasks with obstacles and threats. Neuroticism on the other hand seems to affect positioning, where the virtual threats are not a strong factor, but rather the need to be accurate in the placement to complete the task. So, for example, in experiments where both accuracy and speed are requirements, Neuroticism should be taken into account. Consequently, more targeted experiments are needed to identify how personality traits affect different types of tasks in this context.

PT was the personality trait with a seemingly greater effect in the experiment. Strong correlations have been noted, both with task duration (for 8 out of 15 variables) and hand movement-related data (for all 10 variables), indicating that higher PT can positively affect performance, instead of hindering it, as we had initially hypothesized. Reported correlations span the existence or not of obstacles and threats during selection and positioning tasks, hinting at an effect on the wider user experience in the VE. Participants with higher PT, instead of being more afraid or anxious of the obstacles and threats and performing slower times and higher hand movements than those with lower PT, seemed to complete the tasks quicker and with lower hand movements. To interpret our findings in the remainder of this section we attempt to delve deeper into the concept of Perspective-taking.

5.1 A Closer Look at Perspective-Taking

Perspective-taking has been recognized as a fundamental aspect of human development (Piaget and Inhelder, 1967). Defined as the ability to take on the visual, cognitive, and affective perspective of others, it is considered a highly adaptive skill, vital for a child's social, intellectual, and emotional development (Mori and Cigala, 2016).

PT can be understood as the "assumption of a point of view from which something is presented or assessed and is traceable only in those aspects which correspond with the said point of view" (Graumann, 2002). Visual perspective-taking emerges gradually as children develop, starting from the ability to understand that another person may see things differently from their standing point and then advancing to also understanding how things are organized in space from the said person's point of view (Flavell, 1977).

Piaget (2003) also discusses conceptual perspective-taking in cognitive development, defining "decentration" as the ability to consider how others may perceive a given situation. Conceptual perspective-taking is considered to be improving from childhood to adulthood, starting from an inability to perceive things from another's point of view to a more complex understanding of this point of view, also considering the other person's circumstances (Selman, 1971; Selman and Byrne, 1974).

The benefit of high cognitive perspective-taking has been recognized as an ability not only to support and help others but also advance personal issues, through the understanding of the reason behind another person's actions, that provides an advantage to better manipulate social situations both in personal and professional contexts (Zappalà, 2014).

In the same sense, our study results indicate that Perspective-taking may help a person adjust more successfully, not only in social situations where one needs to understand the perspective of another, but also in an alternate reality where one is experiencing an altogether different perspective than that accustomed to. And in such a case, it seems that a more advanced cognitive Perspective-taking ability gives one an advantage in a VE over a person with a less advanced ability, in relation to task performance.

The effect of Perspective taking in "adaptation," as the tendency to adjust to the environment, in this case the virtual one, seems to be key here. Adaptation is the process by which humans try to match the original experience and the new experience that may not fit together. According to Piaget (2003), there are two processes at work in cognitive development: assimilation and accommodation. Cognitive growth is the result of the constant interweaving of the two, resulting usually from situations where our perceptions do not fit in with what we know or think.

Introduced in a digital world with its own rules, the users find themselves in a position where they have to firstly assimilate its rules and then adjust to them, trying to navigate and act in this new reality. And greater Perspective-taking seems to support them to understand these new rules and adjust to them more quickly. So in our case, greater PT did not lead to a greater fear of the threats and obstacles nor did it become the cause of inferior performance. On the contrary, it helped users adapt and quickly realize that in reality the threat of the obstacles is not a factor to consider while performing the tasks, thus they did not let it become a factor that affected their performance.

5.2 Limitations and Future Work

We consider the implications of this experiment significant in terms of identifying important characteristics of a user model for VR and meriting further investigation in different directions. For example, in our case we examined the effect of PT on performance when users were present for the first time in this specific VE, having to perform the specific tasks. It would also be worth investigating what would be the effect of PT on performance in the case of more prolonged or repeated visits of the user in the same VE. This way it would perhaps be possible to identify if there is indeed a different point in time for each user in which adjustment to the alternate reality takes place, thus removing PT from the equation.

The results and conclusions of this experiment are limited to the specific context of object manipulation-selection and positioning tasks. It is unclear what would be the effect of PT in other types of tasks within the VE, including other basic interactions such as navigation and locomotion, or more complex ones. We thus perceive this work as a starting point for further exploration of the effect of the specific personality traits on other interaction techniques and types of tasks.

Furthermore, in our experiment we selected two main groups of personality traits, the Empathy and FFM ones. These were selected based on previous research on personality traits and their correlations with presence, combined with the authors' exploratory hypotheses on the importance of the specific traits on object manipulation task performance when obstacles are present. Lacking previous research on this specific context in terms of identifying correlations of personality traits and measurable performance, possibly other personality traits such as absorption or locus of control could be potential candidates to exhibit similar or stronger correlations. To this end, this work can only be considered as a starting point for the exploration of the importance of other personality traits as parts of the user model in the context of immersive VE experiments.

6 CONCLUSION

Considering the setting of task performance-related experiments in an immersive VE, users are indeed being transported to an alternate reality with its own rules. And this transfer happens for the users suddenly and with minimum chance for mental preparation. Especially in cases of object manipulation experiments, the participants have little to no time to adjust to the new reality. This cognitive gap between the physical world and their current state, combined with the possible awkwardness or anxiety of participating in an experiment that measures task performance is bound to have an impact on this performance and thus on the results of the experiment itself.

Our study revealed that this impact is not uniform for all users and that differences in PT do play a significant role on user performance, suggesting that a user's PT should indeed be considered as a factor for participant selection and results analysis, especially if the experimental design foresees a between-groups design.

In addition to this application of our findings in experimental design of object manipulation experiments, we argue that the effect of PT on the user experience in VR merits further investigation. Previous work has indeed identified possible correlations of PT with presence, consistent across several presence self-report measures (Kober and Neuper, 2013). However, it is necessary to go beyond the concept of presence to examine the role of this personality trait in other, possibly more concrete aspects of the VR user experience, including immersion, engagement, flow, emotion, etc. (Tcha-Tokey et al., 2016).

Research on the effect of personality traits on these aspects may have direct applications in fields such as VR-based psychotherapy to be able to identify, for example, which clients are most likely to benefit from it (Sacau et al., 2008). Especially considering that there is a significant body of research examining and confirming the effect of VR experiences to prompt greater empathy (Shin, 2018), and Perspective-taking in particular (Schutte and Stilinović, 2017; Barbot and Kaufman, 2020; Ventura et al., 2020), accounting for each user's pre-existing level of PT may help adjust and personalize the process.

The human mind and personality are infinitely complex and one could argue that assigning personality traits a score ignores and undermines this complexity. Constructs for measuring personality, such as the IRI and FFM self-report questionnaires, may not be sufficiently accurate in depicting the personalities of user study participants. Despite their widespread use and many advantages, self-reports suffer from lack of credibility due to biased responding and distorted self-perceptions (McDonald, 2008). Nevertheless, there are ways to overcome the limitations of such measuring approaches, e.g., by incorporating multiple methods to measure personality constructs. With studies using multiple methods, "it is possible to shift latent and unobservable constructs, such as personality, more into the observable realm," and increase the accuracy of measuring the intended theoretical concept. In any case, self-reporting and other instruments in tandem, can become an invaluable tool for HCI interaction research to expand its understanding of the effect of user individuality on user studies and experiments, and to advance its capability to effectively model the user, thus serving the needs of a wide variety of personalization applications.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the Department of Informatics and Telecommunications, National and Kapodistrian University of Athens. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CL in collaboration with AK focused on the conceptual and experimental design for this research. CL focused on the VR interaction related background whereas AK on the related research on personality traits. MR supervised the experimental process and materials, while all three authors contributed as evaluators during the experiments. CL was responsible for the software development and technical aspects of the work and AK for the statistical analysis of the results. The paper authoring was divided amongst the three authors.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2022.860916/full#supplementary-material

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