The Use of Embedded Context-Sensitive Attractors for Clinical Walking Test Guidance in Virtual Reality

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Virtual reality is increasingly used in rehabilitation and can provide additional motivation when working toward therapeutic goals. However, a particular problem for patients regards their ability to plan routes in unfamiliar environments. Therefore, the aim of this study was to explore how visual cues, namely embedded context-sensitive attractors, can guide attention and walking direction in VR, for clinical walking interventions. This study was designed using a butterfly as the embedded context-sensitive attractor, to guide participant locomotion around the clinical figure of eight walk test, to limit the use of verbal instructions. We investigated the effect of varying the number of attractors for figure of eight path following, and whether there are any negative impacts on perceived autonomy or workload. A total of 24 participants took part in the study and completed six attractor conditions in a counterbalanced order. They also experienced a control VE (no attractors) at the beginning and end of the protocol. Each VE condition lasted a duration of 1 min and manipulated the number of attractors to either singular or multiple alongside, the placement of turning markers (virtual trees) used to represent the cones used in clinical settings for the figure of eight walk test. Results suggested that embedded context-sensitive attractors can be used to guide walking direction, following a figure of eight in VR without impacting perceived autonomy, and workload. However, there appears to be a saturation point, with regards to effectiveness of attractors. Too few objects in a VE may reduce feelings of intrinsic motivation, and too many objects in a VE may reduce the effectiveness of attractors for guiding individuals along a figure of eight path. We conclude by indicating future research directions, for attractors and their use as a guide for walking direction.

Keywords: guidance, navigation, virtual reality, virtual environments, virtual rehabilitation, autonomy, self-determination theory, attractors

INTRODUCTION

Virtual Reality (VR) technology may be introduced into both clinical and community-based environments and has supported patients in a range of therapeutic activities. Examples include training for function led tasks (e.g., crossing a road, or shopping in a supermarket) (Corbetta et al., 2015; Dawson and Marcotte, 2017; Parsons et al., 2017), and construct led tasks, sometimes referred
to as “exergames” (Dawson and Marcotte, 2017). Both function led, and construct led tasks can be managed safely (Fox et al., 2009; Borrego et al., 2016), and provide additional motivation in VR (Cikajlo et al., 2020), thus reducing patient boredom, increase patient motivation and compliance to engage with therapeutic activities (Chen et al., 2020). Although, VR supports a variety of different therapeutic activities, explicit instructions are often provided verbally to guide a patient through a task (Johnson et al., 2013; Jie et al., 2018; Mak et al., 2018; Kleynen et al., 2019). Information provided typically regards motor movement and technique performance (Denneman et al., 2018; Gokeler et al., 2019). However, this may increase reliance on declarative knowledge, increasing working memory due to patients having to remember and recall instructions and movement sequences (Buszard et al., 2017), and thus reduce movement automaticity (Denneman et al., 2018; Johnson et al., 2019). Implicit instructions can target these problems (Gokeler et al., 2019; Dahms et al., 2020), focus of implicit instructions in VR may be placed upon how a patient moves, often regarding the adaption of movement, based upon visual guidance (Anglin et al., 2017; Bonnette et al., 2020), for example, some applications have used biofeedback in conjunction with visual shape matching (Bonnette et al., 2020).

A particular challenge for patients when discharged to community-based environments is the ability to plan routes in unfamiliar environments, and partake in outdoor recreational activities (Palstam et al., 2019). This can lead to a decrease in social and familial interaction (Liu and Ng, 2019; Palstam et al., 2019), and thereby a decreased quality of life (Corbetta et al., 2015; Liu and Ng, 2019). Therefore, focus to address this problem could be placed upon introducing scenarios, that develop patient’s route planning and anticipatory movements toward different simulated environments. Additionally, autonomy supported motivation may further support effective motor (re)learning (Wull et al., 2015; Lemos et al., 2017). When a patient responds to controlled events, they might experience less autonomy, as their motivation is generated through controlled means (Keatley et al., 2013). A motivational theory which considers both controlled and autonomous motivation along a continuum is “Self-Determination Theory” (SDT) (Ryan and Deci, 2017). Within SDT there are three fundamental psychological needs including: autonomy, competence and relatedness (Ryan and Deci, 2017). When these needs are fulfilled, they may support patient confidence and may lead to an increase in physical activity (Sweet et al., 2012). Furthermore, it is important that the opportunities for patients to practice their decision making and anticipatory skills are developed within the safety of clinical environments (Johnson et al., 2013), ensuring that patients’ skills are appropriately assessed by clinicians with regards to everyday functional tasks (Jie et al., 2018).

During everyday functional tasks, both curved and straight walking are utilized to navigate around obstacles in an environment (Schack et al., 2019). A widely-used walking intervention which assesses both straight and curved path walking is the “figure of eight walk test” (FO8WT) (Hess et al., 2010; Wong et al., 2013; Welch et al., 2016). However, if focus is placed upon patients’ planning and anticipatory movements when implementing the FO8WT into VR, there needs to be balance between providing enough information to guide the patient along the figure of eight path whilst supporting autonomy to allow the patient to make their own navigational decisions. This raises the question of how the design of VR rehabilitation applications can accommodate the required information for the FO8WT through visual guidance mechanisms to complete relevant clinical activities/assessments, promote aspects of SDT (autonomy, competence, and relatedness), and reduce impact on working memory.

Visual guidance approaches such as manipulation of optic flow for example, increasing vection have previously been used to induce postural adjustments in individuals to alter the direction of navigation during walking (Furukawa et al., 2011). Similarly, redirected and reorientation techniques may make use of environmental and/or perspective manipulation to alter a user’s path in both the virtual environment (VE) and the physical tracked space (Vasylevska et al., 2013; Nilsson et al., 2018). The manipulations introduced in extant literature have meant that users must compensate for differences between visual, vestibular, and somatosensory information to alter their walking direction, often without awareness (Vasylevska et al., 2013; Langbehn et al., 2017). Alongside visual manipulation approaches, haptic feedback can be used to induce changes in walking direction. One example, is the use of robotic guide dogs, who can help to guide the visually impaired safely along paths (Chuang et al., 2018), which may be implemented so that the user holds onto a cane/handle (Chuang et al., 2018), and when the robot turns the user receives haptic feedback based on the mass of the robot indicating movement (Hersh and Johnson, 2010). Another example is galvanic vestibular stimulation in which the placement of electrodes behind an individual’s ear, can induce postural adjustments through the use of electrical currents (Maeda et al., 2005). Galvanic vestibular stimulation has been used to support reorientation techniques. For example, Sra (2017) made use of three different electrical current variations to elicit three different balance responses in order to influence walking direction (Sra, 2017). Even though these approaches have been shown to induce changes in walking directions, they require the user to compensate for any changes, and therefore in this context, it may be that these visual guidance mechanisms may not provide an appropriate level of autonomy.

If we wish to support navigational decisions and autonomy, we need to foster opportunities that can influence guidance, whilst reducing reliance on postural adjustment responses. Instead providing opportunities for individuals to respond as they would like, without negative consequences would appear particularly beneficial. Thus, an important consideration when designing visual guidance with the use of head-mounted display (HMD) VR applications is that the user can look freely around the VE. Consequently it is harder to visually guide their attention toward an intended direction (Gregorick et al., 2018). Whilst traditional visual guidance principles such as signs, maps, and continuous lines can be used in VR to aid in directing attention toward an intended area (Miller, 1992; Vilar et al., 2014), they can be obtrusive, and distracting from a given task (Gregorick et al., 2018). Therefore, subtle approaches to guidance can be
considered, such as manipulation of light and artificial markers (e.g., colored dot) (Grogorick et al., 2018). However, for guidance purposes, current subtle approaches such as a colored dot may not appear natural within in a VE. Consequently, if a VR application is being used within the context of training applications these approaches should be used minimally, to ensure immersion remains high and increases the learning potential of an application (Lin et al., 2012; Cuperus et al., 2018; Grogorick et al., 2018).

VR based research areas such as cinematic VR, use visual saliency to attract attention (Nielsen et al., 2016), whilst redirected and reorientation techniques may make use of distractors as well as attractors in order to guide attention away from manipulations in a VE (Peck et al., 2009; Sra et al., 2018). Distractors used in redirected walking often gravitate toward explicit cues (Peck et al., 2009), where explicit cues are defined by Nielsen and colleagues (Nielsen et al., 2016), as using explicit communication to direct attention toward a certain object (Nielsen et al., 2016), for example with having to keep a distractor within their field of view, to aid unnoticeable rotational manipulations (Peck et al., 2009). Distractors may also be used in conjunction with audio only or a mixture of both visual and audio distractors, to guide navigation in a virtual environment (Rewkowski et al., 2019). In contrast attractors are often embedded into the design of a VE, and become the forefront for interaction within a VE (Sra et al., 2018). In particular embedded context-sensitive attractors are objects which are appropriate within a VE setting, which ensures that they are representative and designed with relation to the task and VE (Sra et al., 2018). However, current attractor approaches, in redirected walking techniques have been used in strict path following scenarios (Sra et al., 2018), and have not explored the design of attractors within autonomy based scenarios. Therefore, the primary aim of this study was to investigate how the design of embedded context-sensitive attractors may guide attention and walking direction in VR, during explorative walking, to invite the completion of the clinical FO8WT. The secondary aim was to ascertain whether the use of embedded context-sensitive attractors provided a sense of autonomy and minimized perceived workload in participants.

MATERIALS AND METHODS

We conducted a within-subjects experiment designed to examine the use of embedded context-sensitive attractors to convey instructions to walk a figure of eight path in a VE, when participants are given the opportunity to explore and of the effect of such attractors on perceived autonomy, and perceived workload. These studies were conducted at the University of Portsmouth (UK), and ethical approval was provided from the Faculty of Creative and Cultural Industries.

Context Embedded-Sensitive Attractor
To examine the effect of attractors and their effectiveness of providing information for completing the clinical FO8WT in VR, the participants were encouraged to explore the VR tracked space, making use of one-to-one mapping. The FO8WT may vary in length from 1.5 \times 1.2 \text{m} (Hess et al., 2010), to the length of 10 \text{m} (Barnett et al., 2016). However, VR room-scale tracking spaces are \sim 5 \text{m} (Langbehn et al., 2017). Therefore, it was decided that the representation of the FO8WT should be smaller than 5 \text{m}, but larger than 2 \text{m} in length to ensure continuity with other room-scale VR setups. Additional considerations include the assessment criteria in the FO8WT i.e., speed, amplitude (number of steps) and the accuracy of their turn (Hess et al., 2010; Odonkor et al., 2013; Barker et al., 2019). Therefore, elements used within the FO8WT such as cones (turning markers) should be considered when implementing the walk test into VR (Hess et al., 2010), being mindful that when represented in a VE, they make logical sense within the context of the setting. However, it is not known whether the use of turning markers will impact the guidance from the attractors. Therefore, turning markers will be present in some VE conditions and not others (Figure 2). Based on the application aiming to provide a sense of autonomy and using visual guidance mechanisms as instructions it was important to move away from architectural spaces and paths to reduce the number of confined paths within the VE (Bruder et al., 2013; Vasylevska et al., 2013; Nilsson et al., 2018). Therefore, in order to implement a VE that is not limited by confined paths, the present study made use of a natural environment—namely a forest—to overcome challenges of scale and shape in the VE, whereby the turning markers were replaced by trees. To, ensure similarity with the FO8WT though, participants started at the center of the FO8WT (Welch et al., 2016).

To ensure that the attractor was easily distinguishable within the VE, saliency properties including color, contrast, form, motion, location and size (Nielsen et al., 2016; Davis et al., 2017), were taken into consideration. Color is a saliency property which is considered relatively stable even with older populations (Davis et al., 2017), and objects which have complementary

![Embedded context-sensitive attractor.](Image 329x93 to 527x308)
colors such as red and green are thought to be more noticeable (Thorpert et al., 2019). However, based on some types of color blindness, it is important to ensure that color is not the only saliency property. Moving objects are reported to attract large amounts of attention (Rothe and Hußmann, 2018; Yang et al., 2018), even in the absence of sounds (Rothe and Hußmann, 2018), and therefore, movement animation was added to the attractors.

To ensure that the attractor was representative of something found in a forest environment a “monarch butterfly” was chosen to represent the attractor(s) (Figure 1). The trees, and attractor were created using 3D Studio Max, and textured using Adobe Photoshop (Tree Material Reference Images (Textures.com, 2017a,b,c,d) and Substance Painter (hand-drawn texture for attractor). Due to the small size of the attractor, and the use of trees to represent turning markers in some conditions, it was
important to acknowledge that dependent on the attractor and participant location visibility to the attractor may be reduced. Therefore, the number of attractors used were altered from either 1–3 (Figure 2). In order to guide walking direction along a figure of eight path, the location of the attractor(s) responded dynamically to participants’ position within the VE. The attractor(s) were programmed to move along the same pre-defined figure of eight path in each VE condition, but only when the participant was moving behind the attractor(s) and along the path in the correct direction. This was implemented with the use of a trigger box (not visible to participants) surrounding the attractors (which was the same size in all VE conditions, including when the attractors are not visible in the control conditions), in which the participants would trigger the attractors movement along the path, if they were behind the attractor(s) but still within the trigger box. The attractors would then move forward along the pre-defined figure of eight path until, the participants were no longer within the trigger box. Therefore, the speed of the attractors was not predefined but kept relative to the speed of the participants. Within eye movement literature, it is suggested that point of gaze is often kept slightly below the horizon line (Foulsham et al., 2011; Vansteenkiste et al., 2014; Tong et al., 2017). Therefore, the position of attractor(s) were kept just below the horizon line, at a height of 1.5 m.

Based upon the attractors introducing an affordance within the VEs, it was hypothesized that the use of attractor(s) will lead to a significant difference in participants following the figure of eight path, when compared to no attractor(s). The implementation of turning markers and increased amount of attractors, were design decisions to ascertain whether they had any impact on guidance, perceived autonomy and perceived workload.

Two Sets of Embedded Context-Sensitive Attractor

Two additional conditions were added to investigate whether participants would always follow the same set of attractors, when presented with two different sets of attractors (1 or 3 Attractors) which moved at the same time in the opposite direction of the figure of eight path (Figure 2).

Participants

Twenty-four Participants (11 Male, 13 Female) aged 21–65 (M = 34.25, SD = 11.29) were recruited from staff and students at the University of Portsmouth, and via word of mouth. All participants completed the experiment and were naïve to all experimental conditions. They did not receive any compensation for taking part in the study. The total duration of the study for each participant was ~1 h.

Procedure

Participants were briefed on the procedure and safety of the study. Once consent was obtained, participants completed a demographics questionnaire (Table 1).

The participants were informed that there were different VEs within this study, and that the researchers would be unable to respond to any questions during the experiment. Their task in each VE remained the same in which they were free to explore the VEs so long as they stayed within the tracked space. Participants were directed to the starting location, indicated by a cross on the floor (Figure 3), and instructed for that VE (which remained the same for each VE) “you have one minute to walk wherever you like, without walking outside of the blue cage, which is for your safety.”

Each participant experienced the attractors based VE conditions in a counter-balanced order, with the control conditions (no attractor and no turning markers), being present both at the very beginning and end of the study. In each condition, participants were given 1 min to explore the VE. The chosen duration of 1 min has been used in a similar assessment of dynamic balance when walking along a FO8 path (Gil-Gómez et al., 2011). In between each VE condition, the participants answered questionnaires, whilst they were seated without the HMD.

The VEs were loaded by the researcher in the pre-defined sequence for each participant once the participants were standing on the starting position and facing the correct direction. The VE faded to black for the 10 s at the beginning of each condition, as an adjustment period for each participant.

Dependent Variables

Participant and attractor(s) trajectories were recorded in cm by measuring the x and y co-ordinates of every 10th of a second, with the participants location was recorded from the position of the HMD. The distance in which participants followed the figure

![Figure 2](image)

**Figure 2**

Two sets of embedded context-sensitive attractors. The figure shows two sets of attractors moving in opposite directions along a predefined figure of eight path, with the participants' movement guided by the attractors. The figure also illustrates the use of a trigger box to control when the attractors are activated.

**Table 1** | Demographics questionnaire results.

| Statement topic       | Scale     | Results |
|-----------------------|-----------|---------|
| Familiarity with VR   | 1 (Very unfamiliar) – | Mdn = 3.5 |
| Participants: 14/24   | 5 (Very familiar) | SD = 1.47 |
| Duration of playing video games | 1 (Under 1 h), 2 (1–3 h), 3 (3–5 h), 4 (5+ h) | Mdn = 2, SD = 0.49 |
| Participants: 13/24   |           |         |
| Frequency of playing video games | 1 (Very infrequent) – | Mdn = 3 |
| Participants: 13/24   |           |         |

**Procedure**

Participants were asked to respond to any questions during the experiment. Their task in each VE remained the same in which they were free to explore the VEs so long as they stayed within the tracked space. Participants were directed to the starting location, indicated by a cross on the floor (Figure 3), and instructed for that VE (which remained the same for each VE) “you have one minute to walk wherever you like, without walking outside of the blue cage, which is for your safety.”

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of eight path was calculated taking the sum of the Euclidean distances calculated from the attractor coordinates. To analyze whether participants followed one particular set of attractors over the other (1 or 3 attractors), the sum of total time followed in seconds was computed. Calculated by taking the smallest Euclidean distance between the participants to the moving attractors indicating whether the participant was following the set with 1 attractor or 3 attractors. Euclidean distance was also used to calculate the largest distance a participant deviated away from the attractor(s).

Self-determination was measured using the 22 statement task evaluation questionnaire (Self-Determination, 2020), which is a subset of the intrinsic motivation inventory (IMI) (Ryan, 1982; Deci et al., 1994). There are four subscales that make up the task evaluation questionnaire including: interest and enjoyment (considered a subscale of intrinsic motivation), perceived competence, perceived choice and pressure/tension (considered as a negative predictor of intrinsic motivation) (Deci et al., 1994). The ending of statement 7 was altered from "I think I did pretty well at this activity, compared to other students” “...to other participants.” Although, each participant would have been the only person currently undertaking the activity of exploring the VE they were asked to make their own judgement of how well they think they did. This statement is used in the calculation of perceived competence (Deci et al., 1994), this subscale needs to be analyzed with consideration that they were naïve to experimental conditions, and were the only people taking part in the experiment at a given time. Therefore, analysis focused upon whether they felt there was any difference within the conditions.

The modified NASA—Task Load Index (NASA-TLX) was used to measure perceived workload (Hart, 2006; Bustamante and Spain, 2008). The chosen approach to using the NASA-TLX was to use the shorter version, as the weighted version can be time consuming (Hart, 2006; Bustamante and Spain, 2008), and may introduce participant errors (Bustamante and Spain, 2008).

RESULTS

There were two participants with tracking issues regarding the first control condition only. One participant had an HMD tracking error, in which they had a fixed offset of −94 on the x axis, for the first control only. Although the participant trajectory can be easily translated, due to the implementation of the attractors correspondence along the figure of eight path raises concerns over accuracy. In addition, another participant completely lost tracking data. Therefore, both participants were excluded from trajectory-based data analysis, for the following variables: following of the attractor(s) and largest distance away from attractor(s), but not the two sets of attractors as this analysis was separate from the control conditions. All statistical analysis used a 95% confidence interval, unless otherwise stated.

Following of Embedded Context-Sensitive Attractor

The total distance in cm, that the participant followed the attractor(s) was not normally distributed at the 5% confidence interval level. Therefore, the non-parametric Friedman Test was used to compare the distance in cm, that the participant followed the attractor(s), in the control (averaged between the control at the beginning and end of the study), compared to the other VE attractor conditions. There was a significant difference $X^2_{(4)} = 15.72, p = 0.003$, with regards to the total distance participants followed the attractor and the VE attractor conditions. Post-hoc analysis with the Wilcoxon signed-rank test were conducted with
The non-parametric Friedman test was used to compare all the task-evaluation variables. There was a significant difference between the use of attractors and turning markers and the perceived interest and enjoyment scores (a measure of intrinsic motivation) $X_{(6)}^2 = 31.56$, $p < 0.000$. *Post-hoc* analysis with the Wilcoxon signed rank test were conducted with a Bonferroni correction applied, resulting in a significance level of $p < 0.005$, there were 5 statistically significant pairings (Table 5).

There was a significant difference between the use of attractors and turning markers and the perceived “Pressure/Tension” (negative predictor of intrinsic motivation) scores $X_{(6)}^2 = 23.52$, $p = 0.001$. *Post-hoc* analysis with the Wilcoxon signed rank test were conducted with a Bonferroni correction applied, resulting in a significance level of $p < 0.005$, there were 2 statistically significant pairings (Table 6).

There was not a significant difference between the use of attractors and turning markers and the perceived competence scores $X_{(6)}^2 = 5.81$, $p = 0.45$. Along with no significant difference between the use of attractors and turning markers, and the perceived choice scores $X_{(6)}^2 = 8.28$, $p = 0.22$ (Table 7).

**NASA-TLX**

The NASA-TLX results from all conditions were analyzed using the non-parametric Friedman Test and there was no statistical difference between any of the VE attractor conditions and the NASA-TLX variables (Mental Demand: $X_{(6)}^2 = 10.64$, $p = 0.10$, Physical Demand: $X_{(6)}^2 = 4.81$, $p = 0.57$, Temporal Demand: $X_{(6)}^2 = 4.59$, $p = 0.60$, Performance: $X_{(6)}^2 = 6.22$, $p = 0.40$, Effort: $X_{(6)}^2 = 7.98$, $p = 0.24$, Frustration: $X_{(6)}^2 = 5.63$, $p = 0.47$, Overall: $X_{(6)}^2 = 5.15$, $p = 0.52$) (Table 8).

**DISCUSSION**

This study explored how the use of visual attractors can be implemented for guidance in completing the clinical FO8WT, whilst keeping verbal instructions minimal. In addition, it examined whether the use of attractors in VEs can negatively impact perceived autonomy and workload. The results from this study indicate that, even when a verbal instruction encourages exploration, the use of attractors can guide walking direction with participants following an implied figure of eight path. This may be due to the implementation of the attractors, in which there is an action and feedback loop provided to participants. Where movement of the attractors along a predefined figure of eight path, occurs if the participant is behind the attractors and within a trigger box (not visible to participants), thus providing a (perceived) affordance for the participants within the VEs (Norman, 1999; Lee et al., 2018). There was also a reduced distance away from the implied path with the introduction of the attractor(s). The use of attractors being effective at supporting guidance for where to move, aligns with existing literature in which visual guidance mechanisms have previously been used to support implicit motor (re)learning, and have focused upon how to move (Anglin et al., 2017; Baird and Stewart, 2018; Bonnette et al., 2020).

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**TABLE 2 | Wilcoxon signed-rank test—distance spent following the attractor.**

| Pairing | Median (cm) | Quartiles | Z val. | P val. | r |
|---------|-------------|-----------|--------|--------|---|
| Control | 79.55 | 41.50–149.53 | −3.62 | < 0.000* | 0.77 |
| A       | 502.93 | 101.32–2031.20 |          |        |    |
| Control | 79.55 | 41.50–149.53 | −3.75 | < 0.000* | 0.80 |
| B       | 276.74 | 190.53–1219.20 |          |        |    |
| Control | 79.55 | 41.50–149.53 | −3.00 | 0.000*  | 0.64 |
| C       | 367.55 | 92.97–954.23  |          |        |    |
| Control | 79.55 | 41.50–149.53 | −2.13 | 0.03   | 0.45 |
| D       | 165.96 | 45.26–649.57  |          |        |    |
| A       | 502.93 | 101.32–2031.20 | −1.19 | 0.24   | 0.25 |
| B       | 276.74 | 190.53–1219.20 | −1.70 | 0.09   | 0.36 |
| A       | 367.55 | 92.97–954.23  | −1.77 | 0.08   | 0.38 |
| C       | 367.55 | 92.97–954.23  | −0.44 | 0.66   | 0.09 |
| A       | 165.96 | 45.26–649.57  | −0.93 | 0.36   | 0.20 |
| B       | 276.74 | 190.53–1219.20 | −1.03 | 0.31   | 0.22 |

Control, Averaged values from the 1st and 2nd control; A, No Turning Markers and 1 Attractor; B, No Turning Markers and 3 Attractors; C, Turning Markers and 1 Attractor; D, Turning Markers and 3 Attractors. *significant value at $p < 0.005$.

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**Two Sets of Attractors**

The total time in seconds, that the participants followed one set of attractors (1 or 3 attractors) and the placement of turning markers in seconds. There was not a significant difference $X_{(2)}^2 = 2.81$, $p = 0.42$ (Table 4).

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**Task-Evaluation Questionnaire**

One participant was removed from statistical analysis within the task-evaluation questionnaire statistics as they had not completed all forms.
Although the attractors were found to be beneficial at guiding participants along a figure of eight path, condition D (Turning markers and 3 attractors) did not significantly differ from the average control (no attractors or turning markers). Upon observation of the participant trajectories there are some emergent patterns. Some participants appear to always follow the attractor; however, there were other participants who decreased in following the attractor when more attractors and turning markers were introduced.

This observation appears to suggest that an increase in objects in a VE may impact the effectiveness of guidance. The reason for this occurrence, may be visual crowding, as objects may become more difficult to differentiate (Whitney and Levi, 2011; Henry and Kohn, 2020). This is often as a result of attention and spatial integration (Henry and Kohn, 2020), in which the distance between objects in an environment are crucial for being able to identify a target object (Bouma, 1970; Whitney and Levi, 2011; Melnik et al., 2020). Although this study did not infer the attractors as a target object, participants may have identified this as a target object within the VE, however visual crowding may have occurred when placing more objects into the VE, making it more difficult to identify the attractors as a target object.

Alternative to the theory of visual crowding (Bouma, 1970), Schmitz and colleagues (Schmitz et al., 2020) suggest that individuals may become desensitized to visual cues, due to constant stimulation. However, it is perhaps unlikely that this explains why following of the implied path in condition D (turning markers and 3 attractors) did not significantly differ from the average control (no attractors or turning markers), as participants only experienced all attractor conditions for a total of 6 min, in a counter-balanced order. This raises important questions as to whether there are saturation points of attractors and other visual methods when guiding attention.

The secondary aim of this study was to ascertain whether the use of attractors provided a sense of autonomy and minimized the impact of perceived workload in participants.
TABLE 3 | Wilcoxon signed-rank test—largest distance away from attractor.

| Pairing          | Median    | Quartiles       | Z val. | P val. | r  |
|------------------|-----------|-----------------|--------|--------|----|
| Control          | 275.92    | 237.95–297.95   | −3.26  | 0.001* | 0.70 |
| A                | 184.56    | 103.07–235.35   |        |        |    |
| Control          | 275.92    | 237.95–297.95   | −2.97  | 0.003* | 0.63 |
| B                | 170.99    | 106.44–251.80   |        |        |    |
| Control          | 275.92    | 237.95–297.95   | −3.33  | 0.001* | 0.71 |
| C                | 215.74    | 159.53–246.81   |        |        |    |
| Control          | 275.92    | 237.95–297.95   | −2.65  | 0.008  | 0.56 |
| D                | 224.51    | 161.66–252.33   |        |        |    |
| A                | 184.56    | 103.07–235.35   | −0.15  | 0.88   | 0.03 |
| B                | 170.99    | 106.44–251.80   |        |        |    |
| A                | 184.56    | 103.07–235.35   | −1.38  | 0.17   | 0.29 |
| C                | 215.74    | 159.53–246.81   |        |        |    |
| Control          | 275.92    | 237.95–297.95   | −1.22  | 0.22   | 0.26 |
| D                | 224.51    | 161.66–252.33   | −1.38  | 0.17   | 0.29 |
| A                | 184.56    | 103.07–235.35   | −0.50  | 0.62   | 0.11 |
| B                | 170.99    | 106.44–251.80   |        |        |    |
| D                | 224.51    | 161.66–252.33   | −0.05  | 0.96   | 0.01 |
| C                | 215.74    | 159.53–246.81   |        |        |    |

Control, Averaged values from the 1st and 2nd control; A, No Turning Markers and 1 Attractor; B, No Turning Markers and 3 Attractors; C, Turning Markers and 1 Attractor; D, Turning Markers and 3 Attractors. *significant value at p < 0.005.

TABLE 4 | Time spent following specific attractor set in seconds.

| Time spent following | Median | Q1   | Q3   |
|----------------------|--------|------|------|
| Condition E–1 Attractor | 4.15  | 0.98 | 8.65 |
| Condition E–3 Attractors | 4.05  | 1.33 | 10.05|
| Condition F–1 Attractor | 3.15  | 0.60 | 6.33 |
| Condition F–3 Attractors | 2.80  | 0.80 | 5.80 |

Condition E, No Turning Markers; Condition F, Turning Markers.

Although this study was conducted with adults that were not undergoing rehabilitation, the results indicated that not only did the design of attractors provide guidance for following an implied figure of eight path but do not negatively impact perceived choice (range 6.7–7) or workload (reported low to medium). The use of attractors was able to provide additional interest and enjoyment results (considered a subscale of intrinsic motivation), when compared to the control (except for condition A). This aligns with other work suggesting that simple scenes can convey information (Nielsen et al., 2016) but that open world environments provide more enjoyment (Ijaz et al., 2020). Furthermore, condition F (2 sets of attractors and turning markers) was perceived to have less pressure/tension than both the control and condition E (2 sets of attractors and no turning markers). Although these were significant differences, it is important to consider that these values were still mid to high for interest and enjoyment and low for pressure and tension. This is a beneficial aspect of the design of attractors,

TABLE 5 | Wilcoxon signed-rank test—interest and enjoyment scores.

| Pairing          | Median    | Quartiles       | Z val. | P val. | r  |
|------------------|-----------|-----------------|--------|--------|----|
| Control          | 4.93      | 4.15–6.15       | −2.00  | 0.05   | 0.42 |
| A                | 5.14      | 4.43–6.57       |        |        |    |
| Control          | 4.93      | 4.15–6.15       | −2.99  | 0.003* | 0.62 |
| B                | 5.14      | 4.71–6.58       |        |        |    |
| Control          | 4.93      | 4.15–6.15       | −2.87  | 0.004* | 0.60 |
| C                | 5.57      | 4.14–6.71       |        |        |    |
| Control          | 4.93      | 4.15–6.15       | −3.46  | 0.001* | 0.72 |
| D                | 6.00      | 4.57–6.86       |        |        |    |
| Control          | 4.93      | 4.15–6.15       | −3.26  | 0.001* | 0.68 |
| E                | 5.86      | 5.14–6.86       |        |        |    |
| Control          | 4.93      | 4.15–6.15       | −2.83  | 0.005* | 0.59 |
| F                | 5.71      | 4.29–6.86       |        |        |    |

Control, Averaged values from the 1st and 2nd control; A, No Turning Markers and 1 Attractor; B, No Turning Markers and 3 Attractors; C, Turning Markers and 1 Attractor; D, Turning Markers and 3 Attractors; E, No Turning Markers—2 sets of Attractors; F, Turning Markers—2 Sets of Attractors. *significant value at p < 0.005.

TABLE 6 | Wilcoxon signed-rank test—pressure/tension scores.

| Pairing          | Median    | Quartiles       | Z val. | P val. | r  |
|------------------|-----------|-----------------|--------|--------|----|
| Control          | 1.60      | 1.30–2.60       | −0.26  | 0.82   | 0.05 |
| A                | 1.20      | 1.00–3.00       |        |        |    |
| Control          | 1.60      | 1.30–2.60       | −0.98  | 0.33   | 0.20 |
| B                | 1.60      | 1.00–2.80       |        |        |    |
| Control          | 1.60      | 1.30–2.60       | −1.29  | 0.20   | 0.27 |
| C                | 1.20      | 1.00–2.40       |        |        |    |
| Control          | 1.60      | 1.30–2.60       | −0.92  | 0.36   | 0.19 |
| D                | 1.20      | 1.00–2.40       |        |        |    |
| Control          | 1.60      | 1.30–2.60       | −1.48  | 0.14   | 0.31 |
| E                | 2.20      | 2.20–2.20       |        |        |    |
| Control          | 1.60      | 1.30–2.60       | −3.13  | 0.002* | 0.65 |
| F                | 1.00      | 1.00–1.20       |        |        |    |
| A                | 1.20      | 1.00–3.00       | 0.44   | 0.66   | 0.09 |
| B                | 1.60      | 1.00–2.80       | 0.74   | 0.46   | 0.15 |
| A                | 1.20      | 1.00–3.00       | 0.74   | 0.46   | 0.15 |
| C                | 1.20      | 1.00–2.40       | −1.09  | 0.27   | 0.23 |
| B                | 1.60      | 1.00–2.80       |        |        |    |
| D                | 1.20      | 1.00–2.40       | −0.20  | 0.84   | 0.04 |
| C                | 1.20      | 1.00–2.40       |        |        |    |
| F                | 1.00      | 1.00–1.20       | −3.74  | 0.000* | 0.78 |
| E                | 2.20      | 2.20–2.20       |        |        |    |

Control, Averaged values from the 1st and 2nd control; A, No Turning Markers and 1 Attractor; B, No Turning Markers and 3 Attractors; C, Turning Markers and 1 Attractor; D, Turning Markers and 3 Attractors; E, No Turning Markers—2 sets of Attractors; F, Turning Markers—2 Sets of Attractors. *significant value at p < 0.005.
as intrinsic motivation may impact learning as a result of the individual behaving in a certain way because they desire to Ryan and Deci (2020). Therefore, it would be interesting to explore the use of attractors in the context of rehabilitation.

Ntoumanis et al. (2020) suggest that self-determination interventions in healthcare could be used to target autonomy, competence and relatedness at different intensity levels. Self-determination was measured in relation to design decisions, of both attractors and turning markers. Even though perceived competence did not significantly differ, in this study were the only individuals participating in the experiment at a given time and were required to be able to walk and stand without difficulty for 1-h. Therefore, in the context of rehabilitation attractors may elicit different perceived competence results, and future research will be needed to explore this further. Therefore, using attractors for guidance to complete clinical tests such as the FO8WT may be best used as an autonomy supportive intervention. Future research could explore, the use of attractors within the context of the FO8WT, but with focus placed upon how a patient moves, along with how they approach each aspect of the FO8WT (e.g., clockwise and anti-clockwise turns). This is particularly important as both curved, and straight walking are utilized in everyday walking (Schack et al., 2019), and require patients to use different muscles (Hess et al., 2010; Wong et al., 2013). This may interlink with research that considers patient confidence regarding their own motor capability, which is argued to interlink with patient motivation and continued recovery (Morris et al., 2017), and whether this may then impact how therapists target different patients motor (re)learning.

Additionally, even though this study had no significant statistical differences for preference of following a specific set of attractors in the two VE conditions where two attractor sets present (condition E and F), future research could explore differences between personal preferences and presenting two different types of attractors and the effect that this may have on guidance within a VE. As personal preference interlinks with the idea of enjoyment, it may explain the reason as to some of the observed behaviors such as participants avoiding the attractor, or always following the attractor regardless of other environmental aspects. Although it was not measured in the study, some of the participants stated that they disliked insects and therefore did not try to follow the butterflies whilst the opposite was true for other participants.

The overall results and observations from this study indicate that attractors can be used as guidance for completing a clinical FO8WT whilst allowing feelings of intrinsic motivation and decision-making opportunities. Although this study was conducted with a non-clinical group of participants, it is

| TABLE 7 | Perceived competence and perceived choice—medians and quartile values. |
|---------------------------|---------------------------|---------------------------|
| **Condition**            | **Perceived competence** | **Perceived choice**     |
|                          | median and quartiles     | median and quartiles     |
| Condition A              | 5.00 (4.00–6.00)         | 6.80 (6.40–7.00)         |
| Condition B              | 4.80 (4.20–6.20)         | 6.80 (6.40–7.00)         |
| Condition C              | 5.00 (4.40–6.00)         | 6.80 (6.60–7.00)         |
| Condition D              | 5.00 (4.00–6.00)         | 6.80 (6.40–7.00)         |
| Condition E              | 4.80 (4.00–6.20)         | 6.80 (6.20–7.00)         |
| Condition F              | 5.00 (4.20–6.20)         | 7.00 (6.40–7.00)         |
| Average Control          | 4.70 (10.40–5.70)        | 6.70 (6.20–7.00)         |

Control, Averaged values from the 1st and 2nd control; A, No Turning Markers and 1 Attractor; B, No Turning Markers and 3 Attractors; C, Turning Markers and 1 Attractor; D, Turning Markers and 3 Attractors; E, No Turning Markers and 2 sets of Attractors; F, Turning Markers and 2 sets of Attractors.

| TABLE 8 | NASA–TLX results. |
|---------------------------|---------------------------|
| **NASA–TLX subscale results** | **A Ave.** |
| **A** Mdn, Q1 and 3 | **B** Mdn, Q1 and 3 | **C** Mdn, Q1 and 3 | **D** Mdn, Q1 and 3 | **E** Mdn, Q1 and 3 | **F** Mdn, Q1 and 3 | **Average** Mdn, Q1 and 3 |
| MD | 15 | 6.25–30 | 6.25–35 | 6.25–30 | 10–30 | 10–33.75 | 11.25–28.75 | 20 | 10–33.75 | 20 | 15 |
| PD | 15 | 6.25–27.5 | 6.25–30 | 6.25–25 | 10–23.75 | 10–28.75 | 6.25–28.75 | 10–23.75 | 10–19.38 |
| TD | 12.5 | 5–28.75 | 6.25–33.75 | 6.25–25 | 10–28.75 | 6.25–28.75 | 5–30 | 7.5–21.25 |
| P | 30 | 10–48.75 | 22.5 | 15–50 | 10–43.75 | 11.25–50 | 10–48.75 | 15.63–47.5 |
| Effort | 15 | 6.25–25 | 6.25–25 | 6.25–23.75 | 10–23.75 | 10–25 | 6.25–25 | 5.63–21.88 |
| Frustration | 10 | 5–18.75 | 5–20 | 5–13.75 | 5–28.75 | 5–23.75 | 5–15 | 5–23.63 |
| Overall | 17.5 | 10–21.27 | 12.71–25.21 | 11.88–24.17 | 12.83–20.17 | 12.71–26.67 | 11.88–26.25 | 11.67–23.12 |

Ave., Averaged values from the 1st and 2nd condition; A, No Turning Markers and 1 Attractor; B, No Turning Markers and 3 Attractors; C, Turning Markers and 1 Attractor; D, Turning Markers and 3 Attractors; E, No Turning Markers and 2 sets of Attractors; F, Turning Markers and 2 sets of Attractors.

MD, Mental Demand; PD, Physical Demand; TD, Temporal Demand; P, Performance; Overall, Overall Cognitive Demand.
important to be mindful when using attractors in clinical settings, to consider the overall design of a VE. Insufficient attractors and additional environment objects may reduce feelings of intrinsic motivation or may become less effective for walking direction guidance. Both were observed in condition A (no turning markers and 1 attractor) and D (turning markers and 3 attractors). Furthermore, it is important to consider when implementing turning markers, the effects this may have on the tightness of turns from participants. For example, fir trees were used to represent turning markers in this application, but trees that are smaller or larger may provide different control with regards to size of turning circles. Furthermore, patient preference may interfere with the effectiveness of guidance so different ecologically valid attractors should be considered. However, it is important to be mindful of visual crowding and saliency as this can cause objects to appear similar (Melnik et al., 2020) and possibly decrease the effectiveness of the attractors. Therefore, we suggest that future research should explore (a) the effectiveness of attractors as instructions, alongside aspects of personal preference and saturation of interest, (b) the impact attractors have on how someone moves, both inside and outside of rehabilitation settings.

DATA AVAILABILITY STATEMENT
The raw data supporting the conclusions 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 University of Portsmouth Faculty of Creative and Cultural Industries. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS
The experiment was designed and conceptualized by CC, BS, and VP. The data acquisition was conducted by CC. Formal analysis was conducted by CC with statistical advice provided from MD. Supervision for this study was completed by WP, MD, BS, and VP. The author who took lead on writing the manuscript was CC and main feedback with edits were provided by WP. All authors contributed feedback to the final version of the manuscript.

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SUPPLEMENTARY MATERIAL
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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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