VIRTUAL REALITY AS A TIME-DISSOLVING MACHINE IN DI-STRESSING MEDICAL TREATMENTS

CURRENT PERSPECTIVES AND FUTURE DIRECTIONS

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Abstract

Time is key in medical treatments requiring the patients to undergo unpleasant sensations. This paper examines how virtual reality (VR) could be used to manipulate treatment time, with specific regard to chemotherapy. After reviewing the relevant literature, the paper focusses on «flow» as the optimal temporal condition to be created in distressing medical treatments. Based on the Dynamic Occupation in Time model, it argues that VR applications may induce flow when expressing appropriately high levels of novelty; complexity; skill demand; user engagement; and focus on activity. Lastly, the paper discusses VR applications meeting these requirements and suitable for implementation in chemotherapy.

Keywords: Virtual Reality, Time Perception, Flow, Medical Treatments, Chemotherapy.

1. INTRODUCTION

The use of virtual reality (VR) is becoming increasingly frequent in several medical contexts (Freeman *et al.* 2017; Dascal *et al*. 2107; Pillai and Mathew 2019). In such contexts, a dimension that is receiving considerable attention is time.

Often, what clinicians are concerned with is the after-treatment time. Indeed, in most cases, VR interventions only prove helpful when they provide durable benefits. One of the clearest example in this regard is rehabilitation (Rose *et al.* 2018).

In other cases, however, what is at stake is rather the time of the treatment itself. In these cases, the planned VR intervention reveals advantageous not much in light of its assumed long-term impact, but rather in relation to the *immediate* effects it produces in the very mo-

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ment of its unfolding. This typically applies to those medical treatments that elicit in the patients high rates of distress, due to the need to endure unpleasant sensations for prolonged temporal intervals. A blatant example in this regard is chemotherapy (Love *et al.* 1989; Chirico *et al*. 2020).

In connection to the latter, VR has been claimed to improve the treatment experience by influencing the patients' *subjective perception of time*. More precisely, according to a series of studies conducted by Schneider and colleagues (2003; 2004; 2007; 2011) and later by Chirico and colleagues (2016), VR would allow to reduce the perceived duration of chemotherapy treatments. Therefore, VR would present itself as a «time-compressing machine», capable of making distressing medical treatments like chemotherapy seemingly shorter, and thus more easily bearable.

Such mode of employment of VR certainly appears promising. However, it may require further and more rigorous investigation. In order to pave the way to such investigation, this paper will go through the following main steps.

First, it will review the existing studies on the effects of VR on perceived duration (i.e duration estimation). By doing so, it will stress the need to take into account a different aspect of time perception (i.e time passage perception) and a specific modality of the latter more in particular (i.e «flow»). Second, the paper will work on a prominent model of time passage perception in order to show how to deliberately produce flow. Lastly, based on this theoretical grounding, the paper will put forward some working hypotheses concerning how to build a VR-based flow-inducing machine.

2. A REVIEW OF THE EXISTING STUDIES: VR, CHEMOTHERAPY, AND PERCEIVED DURATION

As anticipated, the idea of VR as capable of reducing perceived duration has been already tested ~~more~~ with regard to chemotherapy. This section will thus review the existing studies on the topic and highlight both their potential and their shortcomings.

Some seminal studies by Schneider and colleagues will be addressed first (Schneider *et al.* 2003; Schneider *et al.* 2004; Schneider and Hood 2007; Schneider *et al.* 2011). Subsequently, a more recent study by a different research group will be taken into account as well, as it continues the same line of research while improving a key methodological aspect of it (Chirico *et al.* 2016).

Taken together, the studies conducted by Schneider and colleagues were the first and most notable in pointing out how VR determines an «*elapsed time compression effect*» (Schneider *et al.* 2011) when used in the context of chemotherapy, with the duration of treatment time being significantly underestimated in the patients' retrospective duration judgements. However, on closer inspection, they reveal somehow limited.

Schneider and colleagues (2003) collected a sample of 16 women with a breast cancer diagnosis and divided them into two groups. The two groups underwent a VR experience respectively during their first or their second chemotherapy treatment. Four different VR experiences were available, and the participants were allowed to switch across them at their will during the treatment.

Before the start of the experiment, right after the end of the treatment, and 48-52 hours after the end of it, the participants had to answer four sets of questionnaires: the Revised Piper Fatigue Scale (PFS); the State-Anxiety Inventory for Adults (SAI); the Symptom Distress Scale (SDS); and an open-ended questionnaire aimed at an overall evaluation of the VR intervention.

The findings from the above questionnaires were not straightforward. What is most relevant here, however, is that the authors also reported – in terms of an additional finding – a significant time compression effect connected to the use of VR:

> The researcher recorded the amount of time in minutes that the VR was used and also asked participants to estimate the amount of time that they had used the distraction intervention. The average amount of time women thought that they used VR was 43 min, significantly less ($p < 0.001$) than the actual mean recorded time of 78 minutes (Schneider *et al.* 2003, 305).

Though intriguing, this finding seems somehow flawed. Indeed, differently from the three main measures described above, it is not clear that this aspect of the study was controlled. In other words, it appears that a comparison between actual and perceived duration was only performed when participants were using VR, and not also when they were simply receiving chemotherapy. Therefore, there is actually no evidence that VR *specifically* or VR *more than other conditions* promotes the observed time compression effect. In principle, in fact, participants might have reported underestimation, or even greater underestimation, in the absence of any VR intervention as well.

Two subsequent studies led by the same principal investigator (Schneider *et al.* 2004; Schneider and Hood 2007) closely resemble the one just described, in both their procedures and findings. Indeed, in both studies, the duration of the treatment time was significantly underestimated in the chemotherapy sessions involving VR. Once again, however, the patients were not asked to express any temporal judgement when *not* using VR.

Lastly, a further paper by Schneider and colleagues (2011) reports secondary analyses of the data collected in the three studies discussed above. The pooled sample consisted of 137 participants with different cancer diagnoses: breast, lung, and colon cancer.

In these secondary analyses as well, the data concerning time perception showed the expected time compression effect. Indeed, «retrospective estimates of time in chemotherapy with VR immersion averaged 45 min, a 28% underestimate of actual time elapsed (mean = 63 min)» (Schneider *et al.* 2011, 560).

On the one hand, based on the increased body of data to which the 2011 analyses were applied, the idea that VR can work as a time-compressing machine appears strengthened. On the other hand, these analyses still refer to data collected in uncontrolled settings, as they come from the same studies criticized above in this regard. Once again, therefore, it is hard to discriminate whether it is actually VR to impact on the patients' time perception, and to what to degree it is so compared to other conditions.

In light of its methodological nature, the uncontrolled assessment of duration estimation in the studies just examined does not constitute a particularly worrying limitation. Indeed, it could be easily overcome by paying attention to the specific control issue implied. In fact, a different research group has conducted a study that basically replicates Schneider and colleagues' ones, yet introducing a control condition (Chirico *et al.* 2016). In this study, a sample of patients undergoing chemotherapy was divided into two groups: one group was proposed a VR intervention, the other one a music intervention. Retrospective judgements of the treatment time were asked to both groups of patients: the VR group underestimated the duration of the treatment, while the music group overestimated it. Therefore, this work *does* demonstrate in a rigorous way that VR produces a duration compression effect, at the same time showing that an alternative media intervention (i.e. music) does not.

3. FROM DURATION TO TIME PASSAGE: CHASING «FLOW»

Chirico and colleagues managed to overcome the methodological limitation expressed by the previous studies by Schneider and colleagues. Nonetheless, all the above-mentioned studies present a second and rather conceptual limitation.

Such limitation concerns the specific aspect of time perception that the authors chose to target, together with the absence of any preliminary theoretical consideration motivating such choice. Indeed, all the authors at stake focussed exclusively on *duration estimation*: that is, the process of quantifying the amount of time elapsed during a given interval, usually (but not solely: see Bindra and Waksberg 1956) by means of conventional units like seconds or minutes. However, duration estimation alone does not cover the whole domain of time perception. On the contrary, at least one additional aspect of time perception should be taken into account: namely, *time passage perception*.

In contrast to the quantative nature of duration estimation, time passage perception rather refers to the *qualitative* impression of how fast or slow time seemingly passes during a given time interval.

Crucially, in relation to duration estimation, time passage perception constitutes not only an additional, but also a clearly *distinct* aspect of time perception. In the first place, such stance is supported by theoretical and empirical evidence (Wearden 2015; Droit-Volet and Wearden 2016; Cavaletti and Heimann 2019). However, it can be confirmed by more immediate observations as well. Indeed, we often experience, in our everyday life, instances of unproblematic coexistence of duration estimation and time passage perception impressions. For example, when waiting impatiently for something to happen, we may often remain able to calculate the objective amount of minutes elapsed, if asked to do so. Still, when turning to our qualitative sense of time passage, we most likely cannot avoid feeling that time is «dragging» unbearably.

This leads to understand that it would be a methodological mistake to infer duration estimation from time passage perception, or vice versa. In fact, in the case above, a pretty accurate duration judgement would not correspond to an impression of time passing at an ordinary speed. In consequence, when planning a given study, it is necessary to identify in advance which aspect to monitor, and to choose the appropriate respective measures and tasks.

With regard to the issue of VR as a time-compressing machine in distressing medical treatments, the question is thus whether it is duration estimation or time passage perception that has to be «compressed» in order for patients to have an improved treatment experience.

Based as well on the fact that the existing studies have focussed exclusively on duration estimation, it is proposed here that also time passage perception should be devoted specific attention.

The key reason to believe so is that the latter, different from duration estimation, bears a clear and immediate affective valence.

This is supported in the first place by common sense and by corresponding and widespread common sayings. Indeed, it is usually acknowledged that «Time flies when having fun», and in contrast that in boring or unpleasant situations «Time never passes». Importantly, this view has been confirmed by empirical evidence as well. For instance, Wearden and colleagues (2014) tested in a broad sample of participants the impression of speed of time passage in relation to different psychological states and everyday activities. Their results showed that the impression of «Time flying» was elicited by busyness, happiness, and concentration, and by activities like being with friends or beloved ones, and being at parties. On its side, the impression of «Time dragging» was associated with boredom, sadness, and tiredness, and by activities like being engaged in boring work tasks.

If this is the case, *speeding up* the rate of time passage during a chemotherapy session might be at least as important as *shortening* its perceived duration. Therefore, when thinking of temporal compression, it may be sensible to think of a compression of *time passage perception*.

What is interesting now, in light of the scope of this paper, is taking into account one specific modality of time passage perception: namely, that connected to the so-called state of «flow».

Originally developed by Csikszentmihalyi (1975; 1988; 2014), flow essentially consists in an extremely deep, continuous yet effortless absorption in given activities. As such, flow is not strictly or exclusively temporal. Nonetheless, it comprises a peculiar subjective relation with time as well. Indeed, among other accompanying phenomena, it includes a perceived fluidisation of the usual temporal articulation, resulting in a disappearance of time passage. This phenomenon has been described in further works as a sense of «timelessness» (e.g. Larson 2004).

Importantly, flow is associated with an essentially *positive* affective valence. Indeed, flow is also described as «the kind of feeling after which one nostalgically says: «that was fun», or «that was enjoyable»» (Csikszentmihalyi 2014, 136).

On the one hand, this feeling relies on the fact that flow typically induces a suspension of the awareness of the self. Together with one's self, one's worries and concerns temporarily disappear as well (Csikszentmihalyi 2014, 146-147). On the other hand, the positive affective valence of flow relies on the features of the activities inducing it. These activities match quite exactly the individuals' inclinations and abilities. In fact, both too trivial and too demanding activities would counter absorption: the former by leading to «boredom», the latter by inducing «anxiety (Csikszentmihalyi 1975). Moreover, the activities inducing flow normally do not have any external motivation, but they are typically perceived as «intrinsically rewarding» (Csikszentmihalyi 2014, 146).

Based on these observations, it appears appropriate to propose that, when using VR in distressing medical treatments, researchers should go beyond the idea of *speeding up* the patients' time passage perception, and instead attempt to induce a state of flow that would result in *dissolving* time passage perception. Arguably, erasing the treatment time and substituting it with a timeless yet emotionally positive experience would be the ideal outcome of any VR intervention aimed at improving the patients' experience. Hence, VR could be conceived not only as a time-compressing machine, but also – and more radically – as a time-dissolving machine.

To the best of the author's knowledge, whether and how VR may be used to affect time passage perception has not been explored yet in the empirical literature. On its side, and more specifically, flow in VR has been addressed occasionally. However, it was mostly conceived as one among other components of given VR experiences, rather than as their ultimate goal, or in relation to a different reading of the construct at stake than that put forward here (e.g. Reid 2004; Volante *et al.* 2018). These arguably constitute relevant gaps in the literature, which researchers might usefully try to bridge.

In this regard, one reason more to do so is the availability of evidence-based, systematic, and comprehensive models of time passage perception, and flow more in particular. Interestingly, these models can be employed not only to categorize existing situations based on their expected temporal outcome, but also to actively devise new situations in light of a given desired outcome. In a nutshell, what is suggested here is that these models might provide directions as to how to design VR experiences specifically aimed at speeding up or even dissolving time passage.

Based on this suggestion, the next section will present and expand upon one prominent model of time passage perception: namely, Larson's Dynamic Occupation in Time model (DOiT) (2004).

4. A HANDS-ON APPROACH: HOW TO MANIPULATE TIME PASSAGE PERCEPTION

In 2004, Larson presented a highly complex and stratified model named Dynamic Occupation in Time (DOiT), whose aim was accounting for different forms of perceived temporality in relation to various everyday activities.

Larson originally identified six main forms of temporality, corresponding to as many modalities of time passage perception. Among them, four in particular are most relevant here, as they constitute subsequent steps on an ideal continuum of temporal acceleration. These forms of temporality are: protracted duration (i.e. subjective time passing more slowly than clock time); synchronicity (i.e. subjective time passing at equal speed as clock time); compression (i.e. subjective time passing more quickly than clock time); and flow (from Csikszentmihalyi 1988).

As it comprises and draws from it directly, the model is fully compatible with Csikszentmihalyi's original work on the state of flow. Furthermore, as it will be shown, the model has the advantage of providing clear operational directions as to how to obtain this state, by working on precise activity-related and subject-related variables.

For these reasons, the DOiT model appears to constitute a most valuable tool for hypothesising how to use VR to dissolve time passage perception in the context of distressing medical treatments. Going through some related empirical works may help better specifying the functioning of the model itself.

The first of these empirical works was conducted in 2006 by Larson and von Eye, who put to the test selected components of the original DOiT model.

More precisely, the authors focussed on two main factors that are supposed to affect time passage perception when individuals perform given activities. The first one, which was labelled in this study «participant factor», describes the modality according to which individuals experience the activities at stake. It comprises emotional engagement, intellectual engagement, focus on self, and focus on activity. The second one, which was labelled «activity features», refers to some of the traits of the activities themselves, in relation to the individuals' inclinations and abilities. It includes novelty, skill demand, and complexity.

The authors gathered data from 35 participants by using the Experience Sampling Method. 10 times per day, for up to 18 days, participants were asked to mark seven Likert scales assessing the seven components of «activity features» and «participant factor», and one additional Likert scale assessing time passage perception – for a total of eight monitored variables. The data collected were then analysed by means of methods of structural modelling. In the analysis, the activity features were grouped under the label of «NOVCOMP», while the participant factor with its components was named synthetically «ENGAGEMENT». Time passage perception, in turn, appears in the model with the label of «TEMPORALITY».

The authors found a significant path going from NOVCOMP to ENGAGEMENT, suggesting that the novelty, complexity, and skill demand of a given activity contribute to define the way individuals get involved in it. In turn, ENGAGEMENT was connected significantly and reciprocally with TEMPORALITY. More precisely, the two were observed to form a «reinforcement loop». In virtue of such loop, «when a respondent shows a high level of engagement, time flies. When time flies, the individual engages even more strongly, and vice versa» (Larson and von Eye 2006, 126).

In a further study, the authors retrieved the data collected in 2006, yet subjected them to a different analysis (Larson and von Eye 2010).

This time, the components of ENGAGEMENT and NOVCOMP were treated in a dichotomous way, their 2006 ratings being reconverted into «high» or «low». On its side, TEMPORALITY comprised four possible ratings: «same as clock time»; «slower than clock time»; «faster than clock time»; and «lost track of time», or timelessness (i.e. flow). Importantly, the latter was conceived as an extreme form of temporal acceleration, ultimately resulting in a dissolution of time passage itself.

The data underwent a new analysis method, called «configural frequency analysis». The method was used to identify «occupational types», i.e. «patterns of the eight variables that co-occurred more often than expected based on chance» (Larson and von Eye 2010, 157). In simpler words, an occupational type was created whenever different activities – or the same activity recursively – had received the same rating on each of the eight variables under observation (i.e. the four components of ENGAGEMENT, the three components of NOVCOMP, and TEMPORALITY). Additionally, the method was used to identify «composite occupational types», i.e. «set[s] of occupational types that are rated similarly on all variables except for one variable, in this case temporality» (Larson and von Eye 2010, 157). Thus, the purpose of the composite occupational types was to observe which of the four possible forms of temporality emerged as prevalent across groups of activities that shared the same ENGAGEMENT and NOVCOMP ratings.

The third composite occupational type identified by Larson and von Eye is the one that reveals most relevant in view of temporal acceleration, and hence possibly time dissolution. Indeed, as the authors report, it was «three times as likely for time to be perceived as faster than the clock in this composite occupational type» (Larson and von Eye 2010, 160).

On the side of the activity features, i.e. NOVCOMP, the composite occupational type at stake was formed by activities that were high in novelty, complexity, and skill demand. On the side of the participant factor, i.e. ENGAGEMENT, the activities induced high intellectual and emotional involvement, and high focus on the activity. However, they implied a *low* level of focus on the self.

As it can be observed, these ratings match quite precisely Csikszentmihalyi's characterization of the state of flow (i.e. appropriately challenging triggering activities, temporary suspension of the awareness of the self). In fact, as the authors themselves observe, the sense of «losing track of time» (i.e. flow) was the second most frequent temporal outcome connected to the composite occupational type at stake, immediately following temporal compression (frequency rates 44 and 50 respectively). Therefore, as anticipated, the third composite occupational group identified in the study is useful not only in relation to time compression, but in relation to time dissolution as well.

The importance of a low level of focus on the self, or even of its absence, becomes clear when comparing the third composite occupational type with the fourth one identified by the authors. The latter, indeed, only differed from the former with regard to the level of focus on the self, which was rated as *high*. Now, the activities comprised in the third composite occupational type mostly elicited positive feelings like happiness and excitement. On the contrary, those included in the fourth one elicited negative feelings like stress and anxiety. Given that the two types only differed in this regard, the authors infer that an association exists between a high level of focus on the self and the occurrence of negative feelings. In turn, they suggest that such pronounced focus on the self might derive from the fact that the activities in the fourth composite occupational type challenged the participants' ability «beyond a comfortable margin of skill» (Larson and von Eye 2010, 161). Once again, this is in line with Csikszentmihalyi's conceptualization of flow as well. Indeed, as this author observed, flow is undermined when the activities in which individuals engage prove too demanding to them.

In conclusion, and with specific regard to the scope of this paper, Larson and von Eye's insight can be summarised as follows: it is true that high ratings of NOVCOMP generally make time pass more quickly compared to clock time, or even they make time passage disappear; however, activities that prove disproportionately novel, complex, and/or skill-demanding in relation to the individuals' abilities provoke undesired and unpleasant emotional responses.

5. FURTHER DEVELOPMENTS: HOW TO BUILD A VR-BASED TIME-DISSOLVING MACHINE

The conclusive remarks presented at the end of the previous section can finally be transformed into key operational directions regarding how to build the VR-based time-dissolving machine sketched theoretically in section 3.

In this regard, setting the highest goal of building a time-*dissolving* machine might be not only theoretically preferable, but also operationally more convenient. Indeed, flow appears to constitute a further stage of temporal compression. If this is the case, succeeding in achieving flow would meet the ideal outcome of the VR-based manipulation; on the other hand, a partial failure in achieving flow might still result in a hierarchically lower yet satisfactory outcome, i.e. a speeding-up of time passage perception.

When devising a VR-based time-dissolving machine, the main task is the selection of a specific content. Given the occupational frame within which the DOiT model is set, such content should consist in a main activity to be performed within the VR scenario.

First of all, and obviously enough, such activity should have the highest chances possible to elicit a state of flow, or at least to trigger a notable temporal acceleration. In other words, it should be adequately novel, complex, and skill demanding; and it should induce high levels of user engagement, focus on the activity, but not focus on the self.

Arguably, a good starting point to identify an activity with these traits is retrieving those activities that Larson and von Eye (2010) associate, in terms of examples, with the impression of flow in their third composite occupational type: «talking», «working», «writing», «attending classes», «studying», «cooking», «taking exams», and «playing» (Larson and von Eye 2010, 158).

Based on the evidence collected by the authors, all these activities can be taken to be suitable for eliciting flow in everyday situations. However, they should undergo a further review in light of their specific reframing proposed here. This leads to identify three main exclusion criteria.

A first exclusion criterion is connected to the mediated setting in which the activity at stake would be implemented: precisely, VR. Indeed, some of the listed activities may fit poorly a mediated setting, or the mediated setting of VR more particularly. For instance, «talking» is arguably best performed in face-to-face contexts, while «writing» is by definition connected to textual rather than audiovisual and immersive media like VR.

An additional and possibly even more crucial exclusion criterion is connected to the physical context in which the VR-based activity would be performed: namely, that of chemotherapy or similar medical treatments. Indeed, these treatments impose some practical constraints, which are crucial in order for the planned VR machine to be *usable* in the first place.

Chemotherapy, in particular, is most commonly delivered intravenously, with a needle being inserted in the patients' arm or hand. In order for the injection not to be compromised, the patients have to sit and remain reasonably still for the entire duration of the treatment. As a consequence, the activity to be performed in the VR scenario must not require the support of any manual controller. A convenient alternative is represented by *head* movements: for instance, the users may tilt their head on the right when they want to move on the right. Head movements can be assisted by eye movements: for instance, the users may ~~point~~ their gaze at a virtual object when they want to grab it. However, even these types of movements are subject to a further constraint. Indeed, since patients undergoing chemotherapy need to sit still, the required head and eye movements should not exceed the threshold of 180 degrees. These specifications lead to exclude from the list above those activities that may not be easy to perform without any manual control and by relying on simple head and/or eye movements only. This may apply, most likely, to a complex and precise activity like «cooking».

Lastly, it must be noted that – even though it was *overall* linked with positive feelings – the third occupational type also included activities with variably negative emotional correlates. For instance, «working», «studying», or «attending classes» might arguably be perceived as boring by most average users. On its side, «taking exams» is likely to elicit a response of distress in the greatest part of the same users. Such activities should thus be excluded when devising a VR-based temporal machine destined to distressing medical contexts. In these contexts, indeed, intervening on time perception would be pointless or even counterproductive if the intervention was not associated with the emergence of positive emotional feelings.

Taken together, the three exclusion criteria just applied indicate «playing» as the only available activity among those proposed some lines above based on Larson and von Eye's hint (2010). In fact, «playing» is arguably an optimal choice not only because it is not targeted by any of the mentioned exclusion criteria, but also because it has a prominent role within Csikszentmihalyi's original framework (1975; 2014). One of the reasons for this is that the author connects very strictly the notions of play and intrinsic reward, which in turn – as it was explained – is one of the key features of the state of flow. The hypothesised VR-based time-dissolving machine, therefore, could basically be a VR-based playing machine.

Playing in itself, however, is a too broad activity to become operationally relevant. In order to specify it further, it could be reasonable to go back to Larson and von Eye's study (2010), move one step down the temporal hierarchy, and pick one of the activities that the authors associate, within their third composite occupational type, with temporal compression.

Among them, the most suitable appear to be those included in the «driving/riding» couple.

Indeed, it is quite common to find VR applications revolving around the activities of driving and/or riding. Moreover, and more importantly, since in such applications these activities are normally gamified, they may constitute an appropriate VR-inflected instance of the broad activity of «playing».

On the other hand, driving and riding are normally implemented – in applications destined to proper VR headsets – in a way that requires manual controllers, sometimes together with a considerable amount of bodily movement within the physical space. For this reason, an effective option might be exploring the related domain of applications destined to a less sophisticated version of a proper VR headset: namely, the Google Cardboard device. This device consists in a goggle-shaped case made of cardboard, which transforms into a VR viewer when a regular mobile phone is inserted in it. Since no additional hardware component is included in the Google Cardboard set, applications developed for this device normally rely on head and/or eye movements only.

Within the Google Cardboard domain, and with regard to driving, a good example is an application called *VR Racer: Highway Traffic 360 for Cardboard VR* (Mountain Rabbit, updated 2020).

When using this application, users drive a fast car on a two-way highway, and they have to dodge other cars coming from both directions. The movements of the users' car follow the movements of their head, with no other body part being involved, and the view is frontal. The driving experience offered by *VR Racer* is certainly somehow novel, as the game cannot be said to instantiate a usual driving style. Furthermore, it shows an appropriate degree of complexity and skill demand: avoiding crashes with the other vehicles is not easy, but the head control is functional enough for the users to improve their performances quickly. Taken together, these activity features arguably result in a pretty high level of engagement, and in a necessary focus on the activity itself. In contrast, they do not seem to imply the need of a particular focus on the self. Thus, applications like *VR Racer* might be suitable for constituting the core of a VR-based time-dissolving machine.

One of the advantages of VR is that it allows to live experiences that would be impossible in real life. This allows in turn to build on the real-life activities identified by Larson and von Eye, in this case driving, and to enhance some of their key NOVCOMP and/or ENGAGEMENT indicators.

In this regard, a good example is another Google Cardboard application named *Booster VR X-Racer: Aero Racing 3D VR Game* (BoosterGames, updated 2020). Rather than driving in the common sense of the word, users engaging in this application *fly* an aircraft, and they have to avoid obstacles on their way. Once again, the movements of the aircraft are entirely head-controlled, and they do not exceed a 180-degree visual field. Compared to the previous one, with complexity and skill demand being roughly equal, this application arguably features an increased level of novelty, which possibly results in increased levels of engagement. If, following Larson and von Eye (2006), greater engagement is directly linked to temporality, applications like *Booster VR X-Racer* might be even more suitable than regular driving applications when it comes to build the desired VR-based time-dissolving machine.

Though promising, however, the two described applications might share two common problems.

First, in the attempt to avoid obstacles as they drive or fly, the users may move on their chairs more than actually required by the applications – as it happens when one involuntarily leans in various directions together with her/his joystick in a screen-based driving or flying videogame. Such movements would put at risk the effectiveness of the chemotherapy treatment, which – as already mentioned – requires that the patients remain as still as possible.

A second problem is related to the fact that the applications under observation would be employed in particularly long-lasting medical treatments. Indeed, this might result in the driving/flying techniques becoming completely mastered by the user. Hence, the levels of NOVCOMP indicators may start to decrease, together with ENGAGEMENT and TEMPORALITY.

To overcome these possible difficulties, it could be useful to reconsider two of the VR scenarios originally proposed by Schneider and colleagues (2007): namely, *Timelapse* (Hammerhead Entertainment, 1996) and *Titanic: Adventure Out of Time* (Hammerhead Entertainment, 1996). *Timelapse* invites the players to travel across multiple ancient worlds as they solve different enigmas, with the final aim of reaching Atlantis and rescuing a certain professor Nichols. In a similar vein, *Titanic: Adventure Out of Time* proposes the players to engage with mysteries and enigmas while sailing aboard the tragically notorious transatlantic ship.

As they imply a form of manual control (i.e. mouse clicks), *Timelapse* and *Titanic* would not be immediately suitable to be implemented in the desired VR-based time-dissolving machine. However, they are crucial here because they bring to attention the broad class of puzzle games. As it will be shown now, these games have the potential for overcoming both difficulties presented above with regard to driving/flying applications.

First, puzzle games are arguably much less likely than driving/flying ones to induce in the users involuntary bodily movements.

Second, and even more crucially, they appear more suitable for providing sustained temporal dissolution or compression during extended medical treatments. Indeed, puzzle games express a remarkable degree of complexity and they imply an extensive use of a precise type of skills (i.e. logical and/or strategic skills). However, what makes them particularly interesting is that – different from other games like the driving/flying ones previously discussed – their complexity and skill demand does not decrease, but on the contrary increases as playing time increases. Indeed, puzzle game do not require any fixed technique that can be progressively mastered, but rather they challenge the players with ever-changing and often progressively more difficult enigmas. With the levels of the NOVCOMP indicators remaining unaltered in time, ENGAGEMENT would arguably remain constant as well. In turn, this would ensure a more durable effect on the players' time passage perception as well.

The examples introduced in this section in no way aim at being exhaustive. Nonetheless, they do indicate what *types* of VR applications may be taken into account when concretely devising a VR-based time-dissolving machine, and trying to make it effective.

6. CONCLUSIONS, AND FURTHER DIRECTIONS

This paper has proposed how to speed up or even dissolve time passage during distressing medical treatments like chemotherapy, by means of a dedicated VR-based machine. The latter, it was suggested, should have as its core component an activity that: a) expresses appropriately high levels of novelty, complexity, skill demand, user engagement, and focus on the activity itself; b) is suitable for VR implementation; c) is compatible with the practical constraints of a chemotherapy or similar setting; d) matches temporal dissolution with positive emotional feelings. Gamified versions of driving or flying activities, but even more aptly puzzle games involving mind-stimulating activities like solving enigmas were indicated as meeting these requirements.

By proposing the above, this paper has laid the foundations for future empirical works aimed at validating its main claims and – most crucially – the effectiveness of the hypothesised machine. Indeed, the latter should be tested by means of a proper experimental procedure. Such procedure – though shifting the focus from duration estimation to time passage perception – should partially draw from existing studies like those examined in the first section of this paper. However, it should also overcome their most notable limitations. Most importantly, and following Chirico and colleagues' example (2016), it should allow time passage perception to be assessed in a controlled way.

This and similar lines of investigation would arguably promote key advancements in the research path that this paper has tried to pave. Possibly, «better times» are around the corner for patients involved in chemotherapy and similar distressing medical treatments.

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ENDNOTES

[1] These studies have been selected because – within the broader literature on VR in chemotherapy or other distressing medical treatments – they are the only ones to have devoted explicit attention to time perception (Chirico et al. 2015; Hoffman et al. 2019).

[2] It may be objected here that expressions like «Time flies» or «Time drags» simply constitute non-technical or metaphorical ways to refer to duration estimation; or that time passage perception is actually dependent on duration estimation – in a way that «time flying» would correspond to shorter perceived durations and «time dragging» to longer ones. However, empirical evidence has demonstrated that this is not the case. Indeed, in addition to the mentioned literature on the distinction between the two aspects of time perception, further studies examining more precisely this supposed relationship have consistently shown that duration estimation and time passage perception do not go hand in hand, and thus that impressions concerning the latter cannot be inferred from judgements pertaining to the former (e.g. Wearden 2005; Eugeni et al. 2020).

[3] In particular, Volante and colleagues (2018) searched for relations between the reported sense of flow and duration estimation judgements during two different VR experiences. Such choice appears in contrast with the association proposed here – and shared by the DOiT model – between flow and time passage perception. Possibly supporting this latter reading, Volante and colleagues' study at stake gave null results.

[4] It could be observed that Larson herself does not connect explicitly to time passage perception the forms of temporality she addresses. Moreover, as it will be seen, one of them is ambiguously labelled «protracted duration». However, based on their descrip-

tions, the forms of temporality at stake quite clearly pertain to the domain of time passage perception, which is supported by the fact that the DOiT model is normally discussed in the literature in relation to this aspect of time perception (e.g. Wearden 2016).

[5] ~~For sake~~ of completeness, the remaining two are interstitial time (i.e. in-between or waiting time) and temporal rupture (an exceptional and mostly violent disruption of the ordinary sense of time).

[6] This statement may appear at odds with prominent accounts of game involvement (most notably Calleja 2011), according to which mastering fluently the game controls is a requirement for enjoying the game fully. However, Calleja's view may actually very well be compatible with the directions coming from the DOiT model and Csikszentmihalyi's theorisation of flow. Indeed, precisely because it leads to an ideal game experience, the fluency Calleja refers to may very well indicate the ideal intermediate condition in which a given game is not anymore exceedingly difficult, and hence frustrating, but not yet so easy to becoming boring.

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