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ORIGINAL ARTICLE

The effects of scent and game play experience on memory of a virtual environment

R. Tortell · D. P. Luigi · A. Dozois · S. Bouchard · J. F. Morie · D. Ilan

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Abstract Scent has been well documented as having significant effects on emotion (Alaoui-Ismaili in Physiol Behav 62(4):713–720, 1997; Herz et al. in Motiv Emot 28(4):363–383, 2004), learning (Smith et al. in Percept Mot Skills 74(2):339–343, 1992; Morgan in Percept Mot Skills 83(3)(2):1227–1234, 1996), memory (Herz in Am J Psychol 110(4):489–505, 1997) and task performance (Barker et al. in Percept Mot Skills 97(3)(1):1007–1010, 2003). This paper describes an experiment in which environmentally appropriate scent was presented as an additional sensory modality consistent with other aspects of a virtual environment called DarkCon. Subjects' game play habits were recorded as an additional factor for analysis. Subjects were randomly assigned to receive scent during the VE, and/or afterward during a task of recall of the environment. It was hypothesized that scent presentation during the VE would significantly improve recall, and that subjects who were presented with scent during the recall task, in addition to experiencing the scented VE, would perform the best on the recall task. Skin-conductance was a significant predictor of recall, over and above experimental groups. Finally, it was hypothesized that subjects' game play habits would affect both their behavior in and recall of the environment. Results are encouraging to the use of scent in virtual environments, and directions for future research are discussed.

Keywords Virtual environments · Video games · Scent · Olfactory display · Emotion · Arousal · Memory

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R. Tortell (✉) · D. P. Luigi · A. Dozois · S. Bouchard · J. F. Morie · D. Ilan
USC Institute for Creative Technologies, Marina del Rey, CA 90292, USA
e-mail: tortell@stanford.edu

D. P. Luigi
e-mail: luigi@ict.usc.edu

A. Dozois
e-mail: dozois@ict.usc.edu

S. Bouchard
e-mail: bouchard@ict.usc.edu

J. F. Morie
e-mail: morie@ict.usc.edu

D. Ilan
e-mail: ilan@ict.usc.edu

1 Introduction

The sensory environments evaluation (SEE) project set out to demonstrate that more affective immersive training environments could contribute to more effective training systems for soldiers. The project focused on immersive training environments delivered via traditional virtual reality techniques, and began with several related hypotheses:

- Virtual environments for training can be made more emotionally evocative.
- Emotional response in virtual environments tends to increase users' overall physiological arousal states, significantly impacts users' behavior, may

improve immediate recollection of scenario experience, and may enhance retention of scenario experience
- Inclusion of additional sensory modalities in the scenario experience will heighten these responses.

One of the ''additional sensory modalities'' proposed was the delivery of scent consistent with the virtual environment being experienced. Initial experiments dealt with the effects of priming, contained within a mission briefing, on the affective impact of a free-will virtual environment called DarkCon. The DarkCon scenario was built on the premise that the integration of sensory modalities mitigated the need for photo realistic graphics. During initial experimentation, a concept of scent delivery called the ''scent collar'' was formulated. Worn around the neck and shoulders, the collar contains several cartridges of scent that can be triggered either by hand or wirelessly by a computer system. In 2004, working with Anthrotronix, an incubator company from the University of Maryland, an initial version of the scent collar was designed, fabricated and tested, with encouraging results. The latest version of the scent collar, used in the present study, improves on the original design by more accurately focusing the scent release towards the nose (see Fig. 1).

This Scent Collar provides the sense of smell to any immersive environment via an innovative, lightweight and fashionably wearable device. It is designed for use by an individual in a virtual or game environment and is wirelessly controlled via Bluetooth protocols. Areas are created within a 3D environment to define a perimeter or locus for the scent release. Alternatively, a specific event can trigger the release of a scent. The scent collar can provide several scents (the prototype collar, as shown, features four) for use during the experience. Scent research obviates any primal combinatory odorants, thus the required scents are bought or specially mixed to achieve the desired effect. Each unique scent (typically an oil-based mixture) is placed on a wick or cotton ball material. This wick is then placed within a small receptacle in the individual cartridges embedded in the wearable collar. Each cartridge can be cleaned and refilled, so that different scent configurations can be utilized for different environments. The Collar has tunable intensity controls to vary both the amount and duration of the scent being released. Contrasting with commercially available room-filling scent release systems that linger in the air and are difficult to dissipate, the Scent Collar features a much smaller amount of localized odorant molecules that dissipate rapidly.

Fig. 1 The scent collar. The four scent cartridges are visible

The effects of the addition of scent to virtual environments were selected for study based on findings confirming scent as a powerful emotional trigger, when intensity of emotion is measured either by self-report or autonomic nervous system activity (Alaoui-Ismaili et al. 1997). Scent is the sensory modality most closely tied to the neural substrates of emotion, and as such is capable of evoking memories with strong emotional attachment. In fact, scent is most effective as a cue to recall when the memory in question was encoded during a period of high emotional arousal (Herz 1997). The emotional state of the subject during the presentation of odor appears to be reestablished: for instance, subjects who became frustrated while an odor was presented were less motivated to perform tasks when the odor was re-presented 20 min later (Herz et al. 2004). As DarkCon was designed to be emotionally affective, it was expected that scent would serve as an enhancement to the effects of emotion in the environment. It is also the case that the addition of environmentally appropriate scents adds another dimension to the user's experience, increasing the realism of the VE. As Witmer and Singer (1998) suggest, the experience of being present in a virtual or remote environment requires a shift of the user's attention away from his physical location, to a consistent set of sensory stimuli presented as a virtual location. Presentation of scent is another method by which a user's attention can be shifted into the virtual world, heightening his sense of presence. The idea of increasing sensory modalities to improve sense of presence has been empirically supported (for instance, Dinh et al. 1999).

With regard to the training and performance aspects of the environment, scent has been successfully

employed as a contextual cue to enhancement of learning and memory. Smith et al. (1992) demonstrated that a 24-word list was better recalled when the scents presented during initial learning and a relearning session were the same, suggesting context-dependent memory. In a similar study, Morgan et al. (1996) found that the presentation of an ambient odor during learning and several recall phases (15 min, 48 h, and 5 days later, respectively) resulted in no significant decline in memory for a list of 40 adjectives, though no-odor control groups' recall declined significantly. The presentation of scent therefore facilitated recall more than unchanging environmental cues. Scent may also facilitate performance on particular tasks. Subjects performing clerical tasks such as typing and alphabetization in a repeated-measures study were found to perform faster and more accurately during the presentation of peppermint odor than without it (Barker et al. 2003). Consistent with these findings, it was hypothesized that the presentation of scent during both the VE experience and recall of that experience would result in improved recall.

Finally, it is the case that, though they are distinctive in many ways, virtual environments have much in common with typical video games. It is to be expected, therefore, that individuals' prior familiarity with and habits of video game play will have bearing on their experience. According to a recent study of children, time spent playing video or computer games currently exceeds time spent watching television (Christakis et al. 2004), and studies of the potential effects of video games, typically restricted to the study of violence and aggression, have demonstrated that behaviour can be and is affected by frequency of videogame play (Anderson 2004). Significant effects of video game play habits on autonomic nervous system activity were found in previous experiments in DarkCon (as yet unpublished), and therefore it was expected that they would have similar effects in this experiment. Due to differing methods of measurement (see below), it was unclear what form precisely these effects might take.

2 Methods

The DarkCon environment was computed and displayed on a 19 in. Planar PX191 monitor using a custom-built mobile three-node PC cluster running Debian Linux. Sound was delivered through Bose QC-1 noise-cancelling headphones. Subjects navigated the environment using a Logitech Wingman cordless gamepad controller. Subjects were seated, and their head movement was not tracked. This experiment was designed to take place in two phases: experience in the virtual environment, and recall of that experience. This led to a 2×2 factorial design with regard to our recall measure: scent being present or absent during DarkCon, and present or absent during after-action questionnaires. We hypothesized that subjects who experienced scent during both phases would demonstrate the most accurate recall (i.e. more correct identifications), based on previous research on the effects of odor on learning and memory (see above). Scent was delivered using our custom Scent Collar (see Fig. 1). We custom-designed a compound scent from individual source oil-based fragrances that was appropriate for the environment used: a swampy culvert (see Fig. 2).

3 Measurements

Subjects' skin-conductance levels and heart rate were measured during the VE experience. These data were recorded using the BioPac MP150 and Acqknowledge 3.8.1. Heart rate was sampled at 250 Hz and recorded using a BioPac ECG100C in *R*-wave mode; with high and low pass filtering at 0.5 and 35 Hz, respectively. Electrodes were placed in a Lead I configuration on the chest. Skin-conductance was sampled at 150 Hz and recorded using a BioPac GSR100C with gain of 2 μS/V and a low-pass filter at 1.0 Hz. Since these measurements were recorded only in the first phase of the experiment (within the VE), they were analyzed by a comparison between levels of only one of our two factors (i.e. scent present or absent during DarkCon).

Based on data gathered in previous experiments, subjects' self-reported game play frequency was measured as well. Subjects were asked about seven types of game play: first-person shooter (e.g. Quake), strategy/simulation (e.g. Starcraft), adventure/role-playing

Fig. 2 A screenshot of objects on the floor of the culvert

games (e.g. final fantasy games), massively-multiplayer online role-playing games (e.g. World of Warcraft), puzzle games (e.g. Sudoku), games played on a computer, and games played at a console (e.g. GameCube). Subjects were asked, ''On an average day, how many hours do you spend playing... (game type)?'' Our scale was from ''none at all'' (coded 0) to ''five or more hours'' (coded 6). This scale was intended for a much more varied subject base. Due in part to the total number of subjects surveyed, and also to a very large floor effect in responses, it was decided that such specificity was not appropriate, and the results from the first five types of game play were consolidated into a measure of ''plays videogames at all'', which was used as an additional factor in analysis of recall. Console and computer play frequency were not included.

Previous experiments in DarkCon relied on a structured after-action interview of subjects, with such questions as ''What vehicles did you observe in the environment?'' The problem with this methodology was that, due in part to the free-will nature of the environment, there was no way to be sure what things the subject did not remember versus things she/he had in fact never encountered. It was also the case that the interview did not necessarily elicit all the items that the subject recalled from the environment.

The experiment required a test of recall, and not just a measure of likelihood of report. It was therefore decided to measure by recognition. Before the experiment, a list was made of all of the objects that were present in the culvert: for instance, a photo album, or a red light fixture. For each of the 24 real items on the list, a plausible but distinct ''fake'' (i.e. not present) item was added, like a newspaper or a yellow light fixture. The entire list of 48 items (including some sounds) was randomized and presented to the subject as a checklist of four items at a time, with the instruction to ''select from the following list any items that you did not observe in the environment''. The questionnaire was phrased negatively so as to minimize the number of false positives reported by subjects.

4 Procedure

In contrast to the last experiments with DarkCon, in this study subjects were limited to exploring the ''culvert'' section of the environment only, a change implemented in order to clarify data analysis and to accommodate time restrictions. DarkCon was designed to be a free-will environment: an excellent property for a believable VE, but the great deal of potential variability in individual experiences made reliability a difficult challenge for reliability in experimental tasks. Restricting subjects' activity to the culvert area reduced the complexity of each individual's experience.

Twenty-four subjects were recruited from Institute for Creative Technologies staff and interns, and assigned with a block randomization procedure into groups in a 2×2 design: scent on or off during DarkCon, and scent on or off during recall. After being briefed and giving informed consent, subjects were asked to fill out the pre-experiment evaluation questionnaires on a laptop computer. The pre-experiment evaluation consisted of demographic data (i.e. age, race, and gender) and game-play frequency questions. After completing the questionnaire, subjects were fitted with electrodes for recording their heart rate, on their collarbone and lower chest. Subjects were then seated in front of a monitor, and fitted with electrodes on the non-dominant hand for skin-conductance measurement. All subjects, regardless of condition, wore the scent collar loaded with scents for the entirety of the experiment.

Subjects were first guided through an unscented tutorial environment designed to help familiarize them with the control interface: a monitor, stereo headphones, and a wireless game-pad style controller. A simple navigation task within the virtual environment provided us the opportunity to record a baseline measurement of physiological activity, comparable to the subjects' activity in DarkCon. Once familiarity with the interface was established, subjects were read their task instructions. They were told that the next phase of the experiment would take place in a culvert, running beneath a region that might be occupied by hostile military forces, and that their task in this environment was to determine if the culvert had been occupied by paramilitary forces or fleeing refugees, by navigating around the environment and examining evidence. They were given exactly 4 min to do so, and were not told that they would be asked to recall specific items afterward. At the 4 min mark, the subjects had their headphones removed, and were given a laptop to fill out the post-experiment evaluation: recall (as described above) and the virtual environments questionnaire (Usoh et al. 1999). Physiological electrodes were removed after the completion of the questionnaire.

5 Data analysis and results

Four subjects' data were discarded in their entirety due to mechanical error. One subject was lacking the post-experiment evaluation questionnaires. An additional

four subjects were removed from physiological data analysis due to extreme outlying values resulting from poor electrode signal, leaving a total of 16 subjects. Of the eight subjects who had scent during DarkCon, four subjects had scent during recall, four did not. Of the eight subjects who did not have scent during DarkCon, three had scent during recall, and five did not. Ten subjects played videogames at all, while six did not.

The following hypotheses were proposed: (1) Those subjects who experienced DarkCon with scent would recall the environment better than those who experienced it without, (2) Those subjects who were presented with scent during both DarkCon and the recall phase would perform the best on the recall task, (3) That physiological arousal would be positively associated with recall, and four. That videogame play experience would affect participants' behavior in the environment, reflected in differences in correct recall. The null hypothesis was that no independent variable would significantly predict items correctly recalled.

Due to the presence of both categorical and continuous independent variables, ANCOVA was used. Using the method described in Judd and McClelland (1989), the ANCOVA was implemented using multiple linear regression. Contrast codes were chosen to represent categorical variables, such that the parameters of the regression model corresponded to questions of a priori interest, hypothesized answers to which are listed in the above paragraph. These hypotheses were chosen a priori, and were all addressed by the single ANCOVA performed. This did not constitute post hoc analysis, and therefore required no additional correction. Results are described in the following section.

The total number of correct responses to the recall questionnaire was analyzed using the following regression model. The experimental group of each subject (using three variables: scent present or absent during DarkCon, scent present or absent during recall, and their interaction term) was included first. Mean heart rate and skin-conductance proportions from baseline were included as probable indicators of recall. Physiological dependent variables (DVs) were represented as proportions of their counterparts measured during baseline. The value of the DV in question recorded during DarkCon, divided by the value recorded during baseline, indicated proportional departure from baseline levels while controlling for individual difference. In this way, mean heart-rate change (BPM) and mean skin-conductance level change (μS) were calculated. To minimize skew and kurtosis (a measure of whether the data are peaked or flat, relative to a normal distribution), heart rate change was log-transformed. Skin-conductance level change was raised to the power of two. Finally, the model included whether the subject plays videogames, and the interaction term of this variable (plays or does not play) with each of the scent variables.

This resulted in a model with eight parameters. The questions being asked, and the hypothesized answers, required that all variables be taken into consideration in a single model. For instance, it would be meaningless to test the effects of arousal on recall without taking experimental groups into account; and if arousal and scent were both hypothesized to have effects on recall, those potential effects ought to be taken into consideration when examining the effects of game play. Since the research hypotheses refer to a single dependent variable, they were all examined at once, lest the effects of one parameter obscure the effects of another.

It is the case that adding many entirely unrelated parameters to the model would still result in a model that was well fit. However, such an over-fit model would be unlikely to reach the critical value of significance, since the error reduced per parameter would be too low. Having addressed this a priori concern, the full model and resultant analysis follows below.

6 Results

Total correct responses to the recall questionnaire was regressed on scent present/absent during DarkCon phase, scent present/absent during recall phase, the interaction between scent variables, log-transformed mean heart rate proportional to baseline, the inverse of the square of mean SCR level proportional to baseline, whether the subject plays videogames, the interaction of game play and scent during DarkCon, and the interaction of game play and scent during recall. The resultant model had very good fit, with $R^2_{adj} = 0.714$, $F[8,7] = 5.675$, $P = 0.02$. Table 1 shows coefficient, standard error, t and p values for each regressor.

Across all groups, controlling for the effects of physiological variables, scent presented during DarkCon had a significant positive effect on correct responses to the recall questionnaire, $t[7] = 2.942$, $P = 0.02$. The hypothesis that presentation of scent during the VE would improve recall was supported: subjects who experienced DarkCon with scent generated on average 3.03 more correct responses than those who experienced DarkCon without scent.

Scent presented during the recall questionnaire had a significant negative effect across all subjects on correct responses, controlling for physiological variables, $t[7] = 3.535$, $P = 0.01$. Subjects with scent during the recall questionnaire generated on average 2.9 fewer

Table 1 Results of regression analysis on total correct responses to recall questionnaire

Variable	Coefficient	Standard error	*T*	*P*
Intercept	33.419	0.888	–	–
Scent during DarkCon	3.026	1.029	2.942	0.022
Scent during recall	–2.882	0.815	3.535	0.010
Interaction of scent variables	2.095	0.789	2.654	0.033
mean heart rate proportional to baseline (log)	–49.954	26.648	1.875	0.103
Mean SCR level proportional to baseline^{-2}	–20.190	5.013	4.027	0.005
Plays games at all	1.415	0.840	1.684	0.136
Interaction of game play and scent during DarkCon	–4.270	1.479	2.886	0.023
Interaction of game play and scent during recall	-0.218	0.818	0.267	0.797

correct responses than subjects without scent during the recall questionnaire.

Controlling for the effects of game play and physiological variables, a significant positive interaction occurred between scent during DarkCon and scent during recall, $t[7] = 2.654$, $P = 0.03$. See Fig. 3 for a graphical summary of results. Subjects with scent on during DarkCon and off during recall generated 3.82 more correct responses than subjects as a whole across groups. Subjects with scent off during DarkCon and on during recall generated 8.0 fewer responses than subjects as a whole across groups. Subjects with scent in both phases generated 2.24 more correct responses than average. Subjects with no scent in either phase generated 1.94 more correct responses than average.

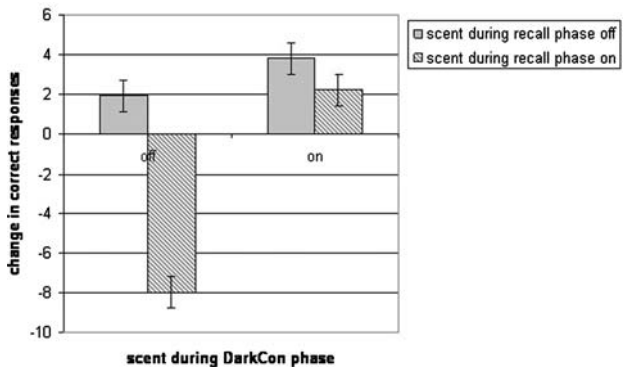

Fig. 3 Mean change in correct responses from overall predicted value for each scent group, when controlling for the effects of all other parameters in the model. *Error bars* represent the standard error of the interaction parameter

Change in heart rate from baseline was not a significant predictor of correct responses, $t[7] = 1.875$, $P = 0.10$.

Across all groups, controlling for the effects of heart rate, change in SCR level from baseline showed a significant negative coefficient, $t[7] = 4.027$, $P < 0.01$. This variable, representing the ratio of mean SCR level during DarkCon to mean SCR level during baseline was transformed as follows: SCR′ = 1/(change in mean SCR from baseline)^2. The negative sign of the coefficient indicates that when the value of SCR′ increases, the number of correct responses decreases. However, taking into account the transformation described above as SCR′ = (1/SCR^2), larger values of the transformed variable SCR′ in fact indicate *smaller* values of the non-transformed variable SCR. The negative coefficient in fact indicates a significant positive effect of mean SCR level on correct responses; supporting the hypothesis that greater physiological arousal would improve memory of the environment.

Across all scent groups, controlling for the effects of physiological variables, game play on its own had no significant effect on correct responses. However, a significant negative interaction appeared between game play and scent presentation during DarkCon, $t[7] = 1.479$, $P = 0.02$. Subjects who played games generated 0.2 more correct responses than average when they experienced DarkCon with scent, while generating 2.66 more correct responses than average when they experienced DarkCon without scent. Subjects who did not play games generated 5.9 more correct responses than average when they experienced DarkCon with scent, but generated 8.7 fewer correct responses than average when they experienced DarkCon without scent (see Fig. 4 for graphical summary). The positive effect on correct responses of scent during the experience was lessened for subjects who played videogames. The interaction of game play and scent presentation during recall was not significant, $t[7] = 0.267$, $P = 0.80$.

7 Discussion

Scent presentation during DarkCon had a positive effect on subjects' recall of the environment, in support of the hypothesis that additional sensory modalities would in fact result in a more immersive experience. This does not seem to be due simply to increased physiological arousal: Pearson correlation analysis showed no significant correlation of scent during DarkCon with heart rate ($r = 0.263$, $P = 0.16$) or skin-conductance ($r = –0.165$, $P = 0.27$). It seems possible

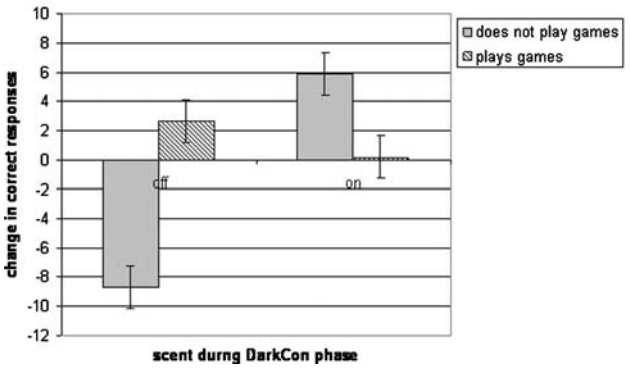

Fig. 4 Mean change in correct responses from overall predicted value for gameplay group and scent present/absent during DarkCon, when controlling for the effects of all other parameters in the model. *Error bars* represent the standard error of the interaction parameter

that scent allowed individuals to more completely focus their attention on the environment, and experience greater levels of immersion (though this itself is admittedly a slippery concept).

No main effect of scent presentation during the recall phase was expected, and so the apparent negative effect was surprising. However, this speaks to the importance of a consistent context of sensory display. The same scent that was contextually appropriate to the DarkCon scenario, and in fact enabled greater memory of the environment, made little or no sense when presented outside that environment, and acted primarily as a distracting stimulus. A subject in this group would never have smelled the odor before, and might additionally be puzzled as to its origin.

The positive interaction between scent conditions supports the initial hypothesis of scent acting as a cue to memory. However, the positive effect of scent being re-presented after already being presented in DarkCon was not strong enough to outweigh the effect of a strongly contextual scent being presented in a context in which it made no sense. The subjects who were presented with scent only during recall performed by far the worst; subjects with scent only during DarkCon performed the best. This contradicts the original hypothesis: even within subjects who had scent in DarkCon, those to whom it was re-presented during recall did not perform as well on the recall task. This finding is interesting especially in the context of results suggesting odor as a trigger for memory. Literature suggests that the effects of odor on memory primarily occur during consolidation; the present study took place in far too short a timeframe to allow consolidation, relying instead upon immediate short-term encoding. It seems likely, therefore, that future experiments involving odor-triggered recollection of a VE take place temporally removed from the experience in order to properly examine this effect.

It is true also that the relative unpleasantness of the odor may have played a role in these results. As discussed, the scent was a murky, swampy, smoky smell, as one might expect to find in an abandoned culvert once used by refugees. This may have compounded the negative or distracting effect that scent had on recall, much more so than a pleasant smell might have.

Though research has been performed in this area with regard to the relative pleasantness of odors (Pauli et al. 1999), few studies have investigated the effectiveness of scents used to enhance virtual environments in particular. Dinh et al. (1999) demonstrate a non-significant trend of olfactory inclusion toward increasing the effectiveness of a virtual environment, but once again included only one scent (coffee, in an office environment). It may seem logical that appropriate scents would be more effective at increasing immersion, but this in particular is an area that invites further study. Morgan's (1996) experiment on presentation of odor during memorization involved taking an odor that was non-valenced, and associating it with encoded memory. In this experiment, the odor was neither neutral nor arbitrary—it was both unpleasant and designed to be appropriate to the environment. The present investigation reveals more than just the general effects of adding scent to a VE. Since subjects who experienced DarkCon with scent had more complete sensory data from the environment, the present study may fairly be said to examine the reaction to a VE when the data is less complete. Is the environment better when more data is added? If users' recall of it is an indicator, it would seem so.

SCR increase from baseline was a significant predictor of correct responses, while heart rate was not. This may speak further to cognitive processing and attention than to visceral arousal. In this case, the cognition exercised during the scenario is reflected in accurate recall afterward. It is important to note that the instruction given to each subject was to gather evidence about a strategic determination, not to memorize the environment. Greater SCR levels unaccompanied by a significant heart rate change seem to indicate greater cognition about the surroundings, and about the given task. The finding supports physiological arousal during the experience as an indicator of recall, regardless of experimental condition.

Of game play and scent during DarkCon groups, people who play videogames performed both best and worst, where subjects who do not play games at all performed much more closely to average. The effect of videogame experience seems twofold. On one hand,

subjects who played games already were likely less motivated to pay attention to this environment that appeared as ''just another game''. However, when scent was included, those who play games—who might have a preexisting interest in novel technology—might have been more impressed by the novel presentation, whereas subjects who do not play games at all were not as affected by the presence or absence of scent. This shows that people who play videogames respond differently to virtual environments than those who do not, possibly for reasons of self-selecting individual difference.

8 Directions for future work

Scent in a virtual environment positively affects subjects' recall of that environment. Is this because it allows people to be more fully immersed in the virtual world, or simply because the appearance of a scent was unusual?

The authors are intrigued by the observed negative effect of scent presented out-of-context during the recall phase. In concert with the effect above, two further directions of study present themselves. Firstly, the importance of scent appropriateness has not been empirically investigated in this area, though it has been examined in the context of product evaluation (Schifferstein and Michaut 2002). How detailed do designers need to be? Is it even necessary that the scent be appropriate, or could it be entirely arbitrary? The authors predict that appropriateness of a scent to the environment being experienced is likely to be a critical factor in creating scent-enhanced VEs.

Secondly, the relative pleasantness or unpleasantness of scent may have effects above and beyond how appropriate it might be. A pleasant smell might put a user at ease, while an unpleasant smell might put them on edge, regardless of context. There is no way to know at this time how the valence of an odor, apart from its realism, might affect perception of a VE. Both odor valence and ''realism'' are distinguishable features of scent addition to a VE, and both require further study if fully immersive environments are to be created.

A final note about game play experience: as it has been demonstrated that people with and without game play experience respond differently to VR, this needs to be taken into consideration in any study that looks at individuals' reactions. As demonstrated above, such an interaction of game play could obscure the desired effect. The authors do not advocate that VEs be designed explicitly for gamers or non-gamers (though obviously, being able to tailor an environment completely to the characteristics of a subject would be ideal); rather, this result and others indicate that it will affect behavior and response, and should not be ignored in future studies.

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