Leaving the third dimension: no measurable evidence for cognitive aftereffects of stereoscopic 3D movies

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Abstract — Stereoscopic 3D (S-3D) is becoming an increasingly important display technology. Parallel to this, concern about the potential negative effects of exposure to S-3D movies has been growing. Some manufacturers place disclaimers on their TVs advising people to limit the time they watch S-3D. However, surprisingly little experimental research has been conducted estimating the genuineness of these concerns. Therefore, an experiment was designed to assess the potential impact of viewing an S-3D movie on visual, spatial, and general attention performance. To mimic the real-world experience of watching a movie in the living room, participants ($N = 61$) watched a full movie in either 2D or S-3D. Our results do not show evidence for cognitive aftereffects of S-3D movies. A second experiment ($N = 32$) that focused on possible aftereffects on visual attention also failed to find reliable effects. We therefore conclude that cognitive functioning is not altered by watching an S-3D movie, at least not to an extent that is measurable through well-established cognitive tasks.

Keywords — *stereoscopic 3D, aftereffects, spatial cognition, visual cognition, mental rotation, change detection, visually directed walking task.*

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1 Introduction

Year after year, more S-3D movies and computer games are released and many TV manufacturers are building televisions that are able to display S-3D images. Hence, the question arises if this technological evolution presents health hazards to our cognitive (i.e., information processing) system. Although major companies place warnings in their S-3D television manuals,[1] hitherto little scientific research has been conducted into its actual aftereffects. As it is conceivable that in the near future, people will watch television in S-3D for many hours, it is necessary to know whether cognitive aftereffects emerge after a certain period of time. In this respect, the domain of spatial cognition is particularly relevant. Many people will engage in visuospatial activities such as driving a car after watching a stereoscopic movie. In this study, we therefore assess if aftereffects of stereoscopic 3D can be found using validated, well-known cognitive tests without compromising ecological validity or the extent to which the experimental conditions approximate the real-world experience.[2]

The principle behind S-3D is to present different images to each eye to mimic the binocular disparity that is inherent to the human visual system (e.g.,[3]). Binocular disparity creates depth perception, because the brain integrates two slightly different images into a single 3D percept.[4] There are many studies dealing with visual discomfort due to S-3D viewing.[5–7] Emoto, Nojiri, and Okano[8] asked participants to watch a stereoscopic movie with polarized glasses for 60 min. Afterwards, they assessed subjective visual fatigue and changes in fusional amplitude. Fusional amplitude is a measure that indicates how good the eyes can fuse separate monocular images into one binocular image. The authors found the fusional amplitude decreased after S-3D, indicating a temporary adaptation to S-3D. After a short relaxation period, the fusional amplitude recovered to a pretesting level. Inoue and Ohzu[9] found that the time to accommodate (i.e., focus) to a real world object differed when a person had just looked at S-3D images. In contrary, Yano, Ide, Mitsuhashi, and Thwaites[6] only occasionally found changes in accommodation after 60 min of watching stereoscopic images. In sum, nearly all of these studies have been conducted in the field of vision research by using optometric measurements. These can be considered as the reflection of low-level perceptual processes, that is, the physiological changes on the level of the eyes. When light has reached the retina, the optic nerve sends a signal to the visual cortex in the brain.[10] However, to *recognize* the visual field, the images also need to be interpreted. This interpretation process is an example of a cognitive process. In short, cognitive measurements can be seen as reflections of higher-level, postperceptual processes.

Given that perception is a prerequisite for subsequent cognitive processing, it could be expected that visual (fatigue) effects (on the perceptual level) also affect cognitive processing performance. Moreover, we know from research into virtual environments (such as gaming research) that "reentry problems" may occur.[11,12] Reentry problems refer to perceptual, cognitive,

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and social disturbances when a person leaves the virtual environment and reenters the real world.[13] We assume that reentry problems are conceptually similar to aftereffects because both arise when adapting to situations with different perceptual and cognitive demands.

This is, to the best of our knowledge, the first empirical attempt at investigating cognitive aftereffects of S-3D. Hence, in the absence of an established theoretical approach, we conducted an experiment by using multiple cognitive performance measures. The first measurement was the performance in mental rotation or the ability to look at an object from another side without physically turning it first. Shepard and Metzler[14] discovered that the time to judge if an object is equal to an identical reference object increases in an almost linear way with the amount of rotation of that object. Their theory was that participants turn the figure in their head at a fixed tempo: the larger the rotation, the longer it will last. We chose mental rotation because it is considered a complex form of spatial cognition[15] and because it has certain generalizability. For example, Stransky, Wilcox, and Dubrowski[16] found that mental rotation training generalized to surgical tasks indicating that any mental rotation deterioration due to stereoscopic viewing can have real-life consequences. Although the mental rotation task is a well-established measure of spatial cognition, we also wanted to use a more ecologically valid measure of spatial cognitive abilities. Therefore, we also adopted the “visually directed walking task".[17–19] In this task, people have to estimate distances ranging from 1 to 20 m. It relies on the ability to mentally estimate spatial distances and is an important skill when driving a car for example. Our third function of interest, nonspatial visual cognition was measured with a variant of the visual binding task,[20] which will be called the change detection task in the following paragraphs. This task is considered as a purely visual task and is mostly used in research into visual working memory.[20] We implemented this task to check if S-3D has an effect on visual cognition besides spatial cognition. In this task, participants see a configuration of a number of colored squares for a short time and have to indicate if a subsequent configuration of squares is the same or not. Finally, the fourth task in our experiment was unrelated to spatial or visual cognition and was implemented to assess the selectivity of possible aftereffects. An effect of S-3D on this task, would be an indication of general fatigue caused by S-3D. We chose a classic initial letter verbal fluency task whereby the participant had to name as many words as possible starting with a certain letter in 1 min. Research has indicated that verbal fluency is a sensitive measure of overall cognitive fatigue.[4]

To investigate the possible influence of S-3D on these cognitive processes, we chose a mixed factorial design. To control for learning and priming effects, we used a Solomon four-group design.[21] This design consists of four different conditions. The first two conditions are the same as in classic pretest–posttest designs: participants do a pretest and a posttest, and in between the variables of interest are manipulated. The last two conditions differ in that there is no pretest. By using this design, we could control for possible pretest sensitization effects.[22] In our study, the independent variable was movie version. Participants saw one out of four movies either in 2D or in S-3D. We chose movies with a realistic playtime, to emulate real-life viewing circumstances. We tested the aftereffect of active S-3D technology whereby the display alternately sends a dedicated image to each eye by shutting down the other eye by using shutter glasses that are synchronized with the screen.

2 Experiment 1

2.1 Method

2.1.1 Participants

Interested candidates filled out an online survey in which they were asked for gender, age, handedness, gaming experience, optical deviations, and experience with S-3D movies. By doing this, we were able to select 64 participants who were matched on S-3D movie and gaming experience. People with optical deviations (no or very poor vision in one eye, strabismus, presbyopia, etc.) were excluded from participation. The gender ratio was equally distributed over conditions. The participants were on average 19.93 years old ($SD = 4.31$) and were paid €8.

2.1.2 Experimental set-up

Images were displayed on Philips 46” 9000 LED series televisions with a diagonal size of 117 cm and a resolution of 1920×1080 pixels. The set-up included two wireless synchronized active LED shutter glasses. The viewing distance was 2.50 m and the television was placed on a platform, 1 m above the ground. We used movies that were available both in 2D and S-3D: “Legend of the guardians” (97 min), “Alice in Wonderland” (102 min), “Sanctum” (107 min), and “Step-up 3” (105 min). Our aim thereby was to use a representative set of the spectrum of available movies in S-3D and avoid material-specific effects that prevent generalization. Each participant was tested on four tasks. Task version was a within-subject factor and was counterbalanced over participants.

2.1.3 Mental rotation task

This task was based on the Vandenberg and Kuse[23] mental rotation test in which geometrical figures were formed by 10 identical cubicles. In this experiment, we showed 80 different pairs of figures per test session. The second figure in a pair could be either a rotated version or a completely different version of the first figure. A trial started with a fixation cross for about 500 ms, followed by the stimulus pair. The participant had to press as fast as possible a left or right button to indicate if the two figures were the same or not. Half of the trials were correct, half of them were incorrect. Feedback was given when the answer was wrong (“Wrong!”). The dependent variable was the reaction time.

2.1.4 Distance estimation task

The second task was the "visually directed walking task".[17] A subject stood at a starting point in the hallway of the university building. The experimenter showed a target position at a distance between 1 and 10 m by placing a cardboard tube on the ground. The subject had to look carefully for 3 s and afterwards he was blindfolded. Next, he had to walk as close as possible to the target position. The dependent variable in this experiment was the final deviation between the end position of the participant and the defined target position. The distances we used in our research were 2.25, 3.60, 5.50, 7.25, 8.10, and 9.30 m, resulting in six trials per test session. The order of distances was randomized for each participant.

2.1.5 Change detection task

In our variant of the Luck and Vogel task,[20] subjects saw either 2, 3, 4, 6, 8, or 12 colored squares on the screen for 100 ms (the sample array). The colors were pseudorandomly chosen out of seven colors (pseudo in the sense that the same colors were used per number of squares in the pretest and posttest). After a blank interval of 900 ms, a test array appeared and the participant had to decide as fast as possible if the stimuli were the same as in the sample array (Fig. 1). In 50% of the trials, the test array was the same as the sample array. In the other 50%, the test array differed in the color of one of the squares. There were two replications of 48 randomized different trials, resulting in 96 trials per test session.

2.1.6 Verbal fluency task

To control for general cognitive fatigue, we implemented a classic verbal fluency task.[24] We asked subjects to generate as many words as possible in 60 s. There were four trials of 60 s with the letters "E","I","W", and "L". Every participant did two trials in the pretest and two trials in the posttest, and letter order was counterbalanced over subjects. The dependent variable was the total number of correct responses.

2.1.7 Procedure

At their arrival, participants filled out an informed consent. Participants in condition 1 and 2 started with the pretest tasks of which the order was counterbalanced. Afterwards, participants went to a separate room and watched the movie side-by-side in a comfortable chair. Only two people could watch a movie at the same time to avoid effects of seating position.[25] They were also instructed not to talk to each other during the entire playtime. The room was completely dark, so there was no disturbing influence of sunlight or direct current sources (e.g., fluorescent tubes) on the shutter mechanisms of the active S-3D system. People were strictly forbidden to take off their glasses. The experimenter frequently inspected the setting to make sure that the participants complied with the respected rules. After the movie, participants from all four conditions went through the posttests.

2.2 Results

2.2.1 Mental rotation task

The first ten trials of every participant were removed because they were considered as the training phase. Next, we removed all trials with an incorrect response. We then checked if our reaction times (RTs) were normally distributed. We saw that the value for kurtosis in the posttest RT was highly positive (3.00), indicating a pointy and heavy-tailed distribution. Therefore, we removed all RTs that were three standard deviations higher or lower than the mean of the correct posttest RTs ($M = 3481.75$, $SD = 39.31$) and pretest RTs ($M = 4283.64$, $SD = 69.60$). This resulted in skewness and kurtosis values of almost zero, indicating a normal distribution. After aggregating the data on the mean RT for every participant, we removed the participants with an accuracy below 60% to prevent that participants who were not mentally rotating and just guessing would blur potential small effects. First, we analyzed the data of condition 1 (S-3D with pretest and posttest) and condition 2 (2D with pretest and posttest). A mixed design ANOVA with test session (pre or post) as within variable and treatment (2D or S-3D) as between variable was executed. There was a main effect of test session, $F(1, 15) = 24.606$, $p < 0.001$, $r = 0.78$, which resembles the well-known training effect involved with the mental rotation paradigm (for a review, see[26]). The interaction between test session (pre or post) and treatment (2D or S-3D) was not significant, $F(1, 15) < 1$, $r = 0.06$. The histogram shows that the means are highly similar, indicating that mental rotation performance after watching a movie in S-3D does not alter differently compared with after watching a movie in 2D (Fig. 2). The analyses described until now did not include the data of conditions 3 and 4. Therefore, a one-way ANOVA with the posttest RTs as dependent variable (mean RT over rotation angles) and treatment (2D or S-3D) as the factor was executed. Again, we used an accuracy cut-off of 60%. The effect of treatment was again not significant, $F(1, 19) = 3.78$, $p = 0.07$, $r = 0.41$.

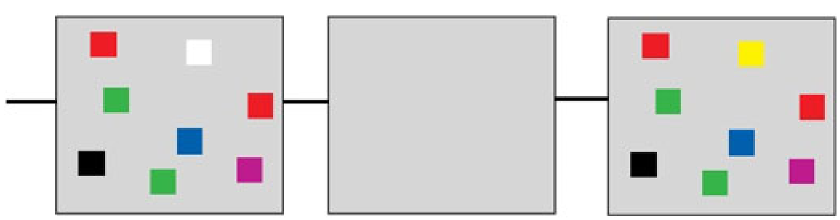

FIGURE 1 — An example of a trial in the change detection task. A sample array (left) is presented for 100 ms, followed by a blank interval (middle) of 900 ms. Next, the test array (right) appears and the participant has to indicate if something has changed or not.

FIGURE 2 — The average reaction times (in ms) in the mental rotation task, displayed for test moment (pre or post) and movie type (2D or S-3D).

2.2.2 Distance estimation task

In this analysis, the dependent variable was distance deviation (absolute value of actual distance – walked distance). A mixed design ANOVA with test session (pre or post) and distance (the six different distances) as within variables was executed. Similar to the previous analyses, treatment (S-3D or 2D) was the between variable. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of distance, $\chi^2(14) = 82.29$, $p < 0.05$ and the interaction between test session and distance, $\chi^2(14) = 54.35$, $p < 0.05$. Therefore, degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity ($\varepsilon = 0.42$ for the main effect of distance and $\varepsilon = 0.42$ for the interaction). We found a main effect of distance, $F(2.12, 59.42) = 24.22$, $p < 0.001$, $r = 0.68$. With increasing distances, the difference between the actual distance and the walked distance is also significantly increasing. The main effect of test session was not significant, $F(1, 28) = 0.83$, $p > 0.05$, $r = 0.17$, and also the three-way interaction between test session, distance and treatment was not significant, $F(2.99, 83.58) = 1.35$, $p > 0.05$, $r = 0.21$. Furthermore, the analysis on the posttest data of conditions 3 and 4 failed to find significant effects of S-3D ($p > 0.05$).

2.2.3 Change detection task

The first 10 trials of every participant were again removed because they were considered as training. Afterwards, we removed all trials with an incorrect response. We again checked if our RTs were normally distributed. We saw that the value for kurtosis in the posttest RT was highly positive (1.72), indicating a pointy and heavy-tailed distribution. Therefore, we removed all RTs that were three SDs higher or lower than the mean of the correct posttest RTs ($M = 1743.80$, $SD = 267.17$) and pretest RTs ($M = 1783.78$, $SD = 293.35$). This resulted in skewness and kurtosis values of almost zero, indicating a normal distribution. The data was aggregated on the mean RT and accuracy per test session for every participant, and per number of colored squares on the screen. Trials with 8 or 12 squares on the screen were excluded from further analyses because they were too difficult and therefore of no use for our experiment. Next, we removed participants with an accuracy lower than 70% for 2, 3, and 4 squares and 55% for 6 squares. A mixed design ANOVA was executed with test session (pre or post) and number of on-screen squares (2, 3, 4, or 6) as within variables and treatment as between variable. We found a significant main effect of test session, $F(1, 6) = 9.84$, $p < 0.05$, $r = 0.79$, and number of on-screen squares, $F(3, 18) = 13.06$, $p < 0.001$, $r = 0.83$. The three-way interaction between test session, number of colored squares and treatment was not significant, $F(3, 18) = 0.80$, $p > 0.05$, $r = 0.34$

The analysis was repeated with the accuracy as dependent variable, but no main and interaction effects were significant. Also the analysis on the posttest data of conditions 3 and 4 failed to find significant effects of S-3D ($p > 0.05$).

2.2.4 Verbal fluency task

The dependent variable in this task was the total number of words participants were able to come up with in 60 s. Per test session, their score was the sum of the performance for two different letters. There were four different letters, which were counterbalanced over participants. A mixed design ANOVA with test session (pre or post) as within variable and treatment as between variable revealed no significant results. The main effect of test session was not significant, $F(1, 28) = 2.62$, $p > 0.05$, $r = 0.29$, indicating that there is no training effect involved in verbal fluency (participants' performance was not increasing). Also the interaction between testing and treatment was not significant, $F(1, 28) = 0.28$, $p > 0.05$, $r = 0.1$. For conditions 3 and 4, we did a one-way ANOVA with total number of words in the posttest as dependent variable and treatment as between variable. The effect of treatment was not significant, $F(1, 30) = 0.42$, $p > 0.05$, $r = 0.12$.

2.2.5 Order effects

Because the design of this experiment was rather complex (pretests and posttests, four different tasks), we looked at possible order effects (the order of the tasks was counterbalanced across participants). A factorial ANOVA with the posttest RT of the visual change detection task as dependent variable and treatment (3D or 2D) and order of tasks (MRT – Distance – Visual, Distance –Visual –MRT, Visual – MRT – Distance) as factors was executed. We found a significant main effect of order, $F(2, 31) = 7.42$, $p < 0.05$, $r = 0.57$, but a nonsignificant interaction between order and treatment, $F(2, 31) = 2.19$, $p > 0.05$, $r = 0.35$. It is therefore very unlikely that task order played a role in our results.

2.3 Discussion experiment 1

We expected that visual fatigue effects on the perceptual level (as previously shown in e.g.,[8]) would also affect cognitive processing performance on higher levels. In contrast to our hypothesis, the general tendency in the results of the different tasks is that S-3D has no observable effect on our cognitive system. First, there were no significant differences between the 2D and S-3D conditions in mental rotation performance. This lack of effect could not be attributed to a type II error (failing to observe a difference that actually exists), because our experiment did have enough power to detect the basic effects of the tasks. There was a significant training effect and a significant effect of mental rotation angle. The first replicates a stable finding in the mental rotation literature: performance improves with training.[27] The second is the core finding of mental rotation: the bigger the rotation angle, the longer the mental rotation lasts.[14] Neither reaction time nor accuracy yielded a clear difference between the conditions. Second, third, and fourth, the visual change detection task,[20] the distance estimation task (real life spatial cognition) and the verbal fluency task (general cognitive fatigue) did not show any difference between 2D and S-3D conditions.

Thus we conclude that there are no observable aftereffects of watching a movie in S-3D on these cognitive processes.

3 Experiment 2

Much optometric research on the topic of visual discomfort related to S-3D viewing has shown an effect on low-level perceptual processes (e.g.,[8,9]). Therefore, we wanted to focus more deeply on a cognitive process which takes place early in the stream of information processing, namely the visual attention. An important paradigm within the field of visual attention is the visual search paradigm.[28] In a visual search task, participants typically have to indicate if a target object is present or not in a display with a number of distractor objects. Our research question was if visual fatigue would affect visual search performance. It has been shown that eye movement ability has a significant effect on visual search[29]: if S-3D fatigues the eye muscles, it could be possible that participants will be slower and/or less accurate. A second experiment with a pretest–posttest design was set up to investigate this question.

3.1 Method

3.1.1 Participants

A total of 32 students ranging from 18 to 26 years ($M = 21.53$, $SD = 2.37$) participated in the experiment and were paid €10 for participation.

3.1.2 Experimental set-up

Both 2D and S-3D images were shown on a Philips 46” 9000 LED series television. Because we did not find any effect of movie content in the previous study, we now used two different movies, that is, “Step up 3” and “Alice in Wonderland”. For each movie, we had again a 2D and a S-3D version. Instead of using a full-length movie, participants watched for 60 m, which is the length mostly used in previous research.[8,6]

3.1.3 Visual search task

We programmed a visual search task comparable with that of Treisman and Gelade[28] by using displays with 1, 5, 15, 30, and 50 stimuli. The distractors were brown letters “T” (50%) or green letters “X” (50%). The target was a blue letter or the letter “S”. These targets were present in 50% of the trials, but absent in the other 50%. There were 160 randomized trials, including two replications of 80 different displays. A trial started with the presentation of a fixation cross for 1500 ms. This fixation display was immediately followed by the stimulus display (see Fig. 3). Participants were instructed to answer as fast and correct as possible by pressing the right button when the target was present and pressing the left button when the target was absent. In case of an error, feedback was given (“incorrect!”) to ensure that participants did not forget the instructions of the task and to encourage them to be more correct. The dependent variable of interest was the reaction time in milliseconds.

3.1.4 Procedure

At their arrival, participants filled in the standard informed consent for experiments at the faculty. All of the participants had to take part in a pretest and a posttest session. In both sessions they conducted the visual search task. The settings and the apparatus of the lab were the same as in experiment 1. In the posttest, all participants filled in a questionnaire about their visual fatigue to check if there was a relationship between the individual perception of visual discomfort and the task performance (cf. Yang *et al.*[25]) This questionnaire was based on the negative effects section of the ITC- Sense of Presence Inventory[30] and consisted of 13 items measured on a 5-point Likert scale.

3.2 Results

3.2.1 Visual discomfort

Exploratory factor analysis was used to check if the 13 items in the visual discomfort questionnaire did measure the visual

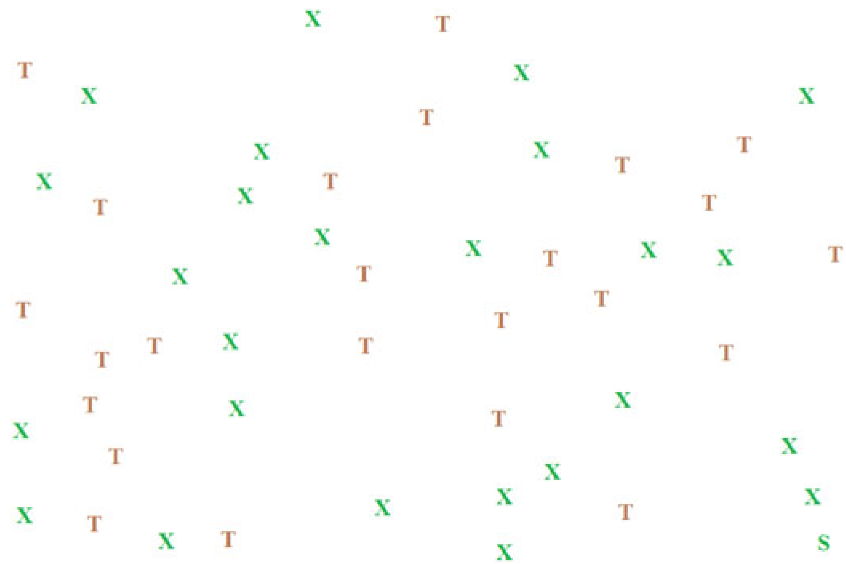

FIGURE 3 — An example of a trial in the visual search task. A number of stimuli are presented and the participant has to indicate if a target is present or not. In this case, the target is a green letter "S".

discomfort construct. Two items were excluded because of poor factor loadings ("I had dry eyes" and "I had stiff shoulders and a stiff neck"). A two-way ANOVA with the self-reported visual discomfort as dependent variable and the variables treatment (2D or S-3D) and movie (Alice in Wonderland or Step Up 3) as factors was executed. Results showed a main effect of treatment, $F(1, 28) = 11.06$, $p = 0.002$, $r = 0.53$, indicating that people who saw the movie in S-3D experienced more visual discomfort. The effect of movie and the interaction between movie and treatment were not significant.

3.2.2 Visual search task

For every participant, the first 10 trials were excluded because they were considered as a training phase. Next, we removed all incorrect trials. We then checked if our RTs were normally distributed. We saw that the value for kurtosis was highly positive in both pretest RTs (2.72) and posttest RTs (2.71), indicating a pointy and heavy-tailed distribution. Therefore, all RTs 3SDs higher or lower than the mean of the correct pretest RTs ($M = 1428.65$, $SD = 806.40$) and posttest RTs ($M = 1301.97$, $SD = 704.34$) were removed. This resulted in skewness and kurtosis values of almost zero (0.72 for pretest RTs and 0.74 for posttest RTs), indicating a normal distribution. The data was aggregated on the mean RT per test session for every participant (pre or post), per number of stimuli on the screen (1, 5, 15, 30, or 50 stimuli) and per presence of the target (yes or no).

First, we looked at the RT for trials in which the target was present (Fig. 4). A mixed design ANOVA with test session (pre or post) and display size (1, 5, 15, 30 or 50 on-screen stimuli) as within variables, treatment (2D or S-3D) as between variable and visual discomfort as a covariate was executed. Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of display size, $\chi^2(9) = 31.88$, $p < 0.05$. Therefore degrees of freedom were corrected using Greenhouse–Geisser estimates of sphericity ($\varepsilon = 0.68$). There was a significant main effect of display size, $F(2.71, 78.63) = 6.06$, $p = 0.001$, $r = 0.41$, indicating that a large number of on-screen stimuli results in prolonged search duration. There was no significant effect of treatment (2D or S-3D), showing that the RTs of people in the 2D and S-3D condition were generally the same, $F(1, 29) < 1$, $r = 0$. The effect of test session was not significant, $F(1, 29) = 1.27$, $F < 1$, $r = 0.20$, indicating that there was no observable training effect from pretest to posttest. All other interactions were also not significant, $F < 1$.

Second, we looked at the RT for trials in which the target was not present. A mixed design ANOVA with test session (pre or post) and display size (1, 5, 15, 30, or 50 on-screen stimuli) as within variables, treatment (2D or S-3D) as between variable and visual discomfort as covariate was executed. Again, Mauchly's test indicated that the assumption of sphericity had been violated for the main effect of display size, $\chi^2(9) = 123.12$, $p < 0.05$. Therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.35$). The effect of treatment (2D or S-3D), was not significant, indicating that the RTs of people in the 2D and S-3D condition were generally the same, $F(1, 29) < 1$, $r = 0.21$. Next to a significant main effect of display size, $F(1.41, 40.84) = 11.80$, $p < 0.001$, $r = 0.54$, there was also a significant main effect of test session (pre or post), $F(1, 29) = 5.77$, $p = 0.02$, $r = 0.41$. This last effect can be seen as a training effect.

3.3 Discussion experiment 2

Regarding the subjective measurements, there was a significant effect of condition (2D or S-3D) on self-reported visual discomfort: people who watched a movie in S-3D had more complaints about their viewing experience. The main research question in this second experiment was if S-3D would affect

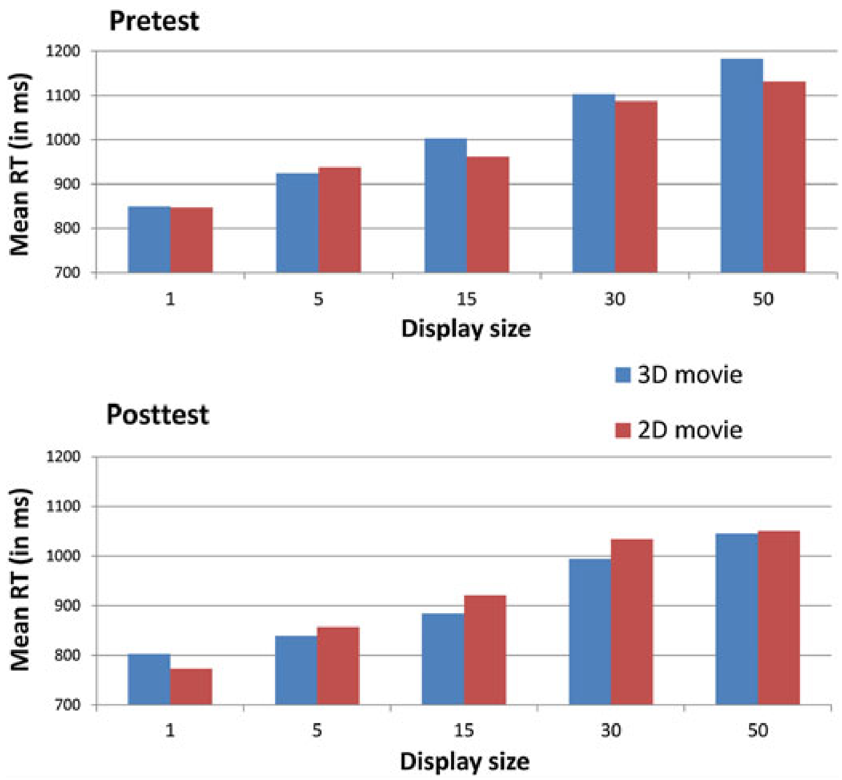

FIGURE 4 — The average reaction times (in ms) in the visual search task (target present), displayed for test moment (pre or post), display size (1, 5, 15, 30, or 50), and movie type (2D or S-3D).

the performance in a classic visual search task. However, our findings show that there is no difference between the 2D and the S-3D condition in RT. For none of the display sizes, the mean RT differed significantly between the 2D and the S-3D group. As for experiment 1, we believe the task was sensitive enough to detect potential effects of S-3D and because we were able to replicate the basic effects of visual search, a type II error is unlikely.

4 Conclusion

Our motivation to study the cognitive aftereffects of S-3D was the observation that manufacturers use disclaimers advising consumers to watch S-3D only for a short period and to avoid car driving directly after exposure to stereoscopic viewing. Our aim was to test the scientific basis of these concerns by measuring the effect of S-3D on cognitive functioning by using widespread, validated techniques. Thereby, special attention was paid to the ecological validity of the design, so that results would be generalizable to real-life situations. At the moment, we are inclined to say there is no measurable effect of watching S-3D on cognitive functioning. We cannot firmly state that cognitive aftereffects of S-3D do not exist, but we can conclude that, if they do exist, they are apparently not measurable through measures of cognitive performance that have been widely used in different contexts for decades. As a consequence, we believe that, even if there is an effect, its size is too small to affect more complex real-life tasks such as driving a car.

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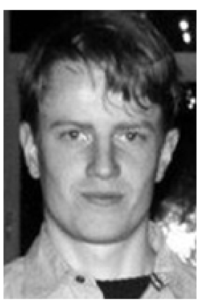

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