The Eye of Emotion: Eye Movement During Emotional Future Thinking

Mohamad El Haj[1, 2, 3] *and Ahmed A. Moustafa*[4, 5]

[1] Nantes Université, Univ Angers, Laboratoire de Psychologie des Pays de la Loire (LPPL - EA 4638), F-44000 Nantes, France

[2] CHU Nantes, Clinical Gerontology Department, Bd Jacques Monod, F44093, Nantes, France

[3] Institut Universitaire de France, Paris, France

[4] School of Psychology, Faculty of Society and Design, Bond University, Gold Coast, Queensland, Australia

[5] Department of Human Anatomy and Physiology, the Faculty of Health Sciences, University of Johannesburg, South Africa.

ABSTRACT

Future thinking is intimately linked with emotions, as projecting oneself into the future typically involves a construction of positive situations that one strives to achieve or negative situations that one seeks to avoid. Therefore, the current study evaluated eye movement during neutral, positive, and negative future thinking. We invited participants to imagine neutral, past, and negative future events while their scan path was recorded by an eye tracker. The analysis demonstrated more and shorter fixations during positive and negative emotional thinking than during neutral future thinking. No statistically significant differences were observed between neutral and positive or negative future thinking regarding the number, duration, or amplitude of the saccades. Comparisons between positive and negative future thinking demonstrated no significant differences on the characteristics of fixations or saccades. Compared to neutral future thinking, emotional future thinking may involve less complex visual representation. However, positive and negative future thinking may trigger similar processing of visual representations.

KEYWORDS

emotion
emotional future thinking
eye movement
future thinking

INTRODUCTION

Future thinking refers to the ability to imagine or simulate events that might occur in the future (Schacter et al., 2017; Suddendorf, 2010). The amount of time we spend projecting ourselves into the future is significant and far from trivial. During a typical day, young adults experience, on average, around sixty thoughts about the future (D'Argembeau et al., 2011). Moments spent on future thinking are not without purpose. Future thinking in general helps to cope with the vicissitudes of daily life (Killingsworth & Gilbert, 2010). From an adaptive perspective, future thinking serves to facilitate decision-making processes by providing a virtual platform on which decisions can be appraised, adjusted, and optimized, which improves the ability to deal with everyday problems and, consequently, action planning (Berntsen & Bohn, 2010; D'Argembeau et al., 2011; Stawarczyk & D'Argembeau, 2015; Suddendorf & Busby, 2005). Critically, future thinking is intimately linked with emotional processing, as projecting oneself into the future typically involves a construction of positive situations that one strives to achieve or negative situations that one would rather avoid (Barsics et al., 2016; D'Argembeau et al., 2011; D'Argembeau & Van der Linden, 2012; El Haj, Antoine, et al., 2017). In this study, we investigated whether emotional future thinking may activate specific eye movement. We conducted this study not only because there is a lack of research on eye movement that may be triggered by emotional future thinking, but, critically, to inquire whether eye movement can be used as a behavioral index of emotional future thinking.

Both past and future thinking activates common neural correlates comprising the medial temporal lobe, precuneus, inferior temporal gyrus, and the posterior cingulate cortex (Schacter et al., 2017). Critically, future thinking activates areas in the prefrontal cortex, which is involved in emotional regulation, and research has demonstrated abnormality in prefrontal cortex activity during future thinking in populations with emotional disturbances (Yang et al., 2019). When projecting ourselves into the future, people tend to experience intense emotional reactions, which, in turn, influence motivation, behavioral intentions, and, ultimately, behavior (Baumgartner et al., 2008). Future thinking can be even more emotionally evocative than past thinking (Berntsen & Bohn, 2010; Finnbogadóttir & Berntsen, 2013). Research has demonstrated that future thinking triggers more positive and idyllic vision than past thinking. This research fits with the assumption that people without pathological conditions (e.g., people without depression), are optimistic about the future and tend to conceive of it in a

Corresponding author: Mohamad El Haj, Faculté de Psychologie, LPPL – Laboratoire de Psychologie des Pays de la Loire, Université de Nantes, Chemin de la Censive du Tertre, BP 81227, 44312 Nantes Cedex 3, France

Email: mohamad.elhaj@univ-nantes.fr

favorable light (Sharot et al., 2007). Furthermore, compared with negative future thinking, positive future thinking is typically more frequent and is imagined faster (D'Argembeau et al., 2011; Newby-Clark & Ross, 2003), triggers more sensory details, clearer representations of contextual information, and more feelings of pre-experiencing (D'Argembeau & Van der Linden, 2004; de Vito et al., 2015). Compared to negative future thinking, positive future thinking also plays a central role in maintaining self-image (Rasmussen & Berntsen, 2013).

In a comprehensive study on the characteristics and functions of emotional future thinking, Barsics et al. (2016) invited participants to record and rate the characteristics of future thinking as occurring in daily life, its emotional properties, and perceived functions. Results demonstrated that emotional future thinking was frequent, occurred in various contexts, and was perceived to fulfill functions such as goal pursuit and emotion regulation. These functions also varied according to the intensity of emotions, the personal importance of the imagined events, as well as the amount of visual imagery as associated with these events. The involvement of visual imagery in future thinking, as demonstrated by Barsics et al. (2016), fits with the consideration that future thinking is intimately linked with mental imagery (El Haj & Lenoble, 2018).

The involvement of mental imagery in future thinking has also been highlighted by research on eye movement during future thinking. Eye movement during future thinking was evaluated by El Haj and Lenoble (2018) who invited participants to imagine future events and to retrieve past events while their scan path was recorded by an eye tracker. Results demonstrated that future thinking triggered fewer fixations and saccade counts than past thinking. The authors attributed the fixations and saccades, as observed during past and future thinking, to mental imagery and, more specifically, to the attempt by the visual system to find (through saccades) and activate (through fixations) stored mental representations. While the study by El Haj and Lenoble (2018) was the first to investigate eye movement during future thinking, it did not investigate the emotional characteristics of the imagined events. However, another study has evaluated eye movement during emotional past thinking by inviting participants to retrieve positive, negative, and neutral memories while their scan path was recorded by an eye tracker (El Haj, Nandrino, et al., 2017). During retrieval, the participants wore eye tracking glasses and faced a white wall. Results demonstrated that emotional (i.e., positive and negative) memories triggered more fixations and saccades. Fixation duration was also shorter during retrieval of emotional memories than during retrieval of neutral memories. No statistically significant differences were observed between emotional and neutral memories for duration and amplitude of the saccades. Regarding comparisons between positive and negative memories, they triggered a similar number of fixations and saccades, similar fixation duration, similar duration of saccades, and similar amplitude of saccades. These findings demonstrate similarities between positive and negative memories on eye movement. Building on these results, we investigated whether these similarities may also be observed for positive and negative future thinking.

Taken together, and building on research demonstrating how future thinking is intimately linked with emotional processes (Barsics et al., 2016; D'Argembeau et al., 2011; D'Argembeau & Van der Linden, 2004), we investigated eye movement during emotional future thinking. Our study was also motivated by research demonstrating how specific eye movement can be observed during emotional past thinking (El Haj, Nandrino, et al., 2017) and general future thinking (El Haj & Lenoble, 2018). Importantly, prior research on eye movement during future thinking (El Haj & Lenoble, 2018) was not concerned with investigating emotional processes related to this kind of thinking. We expected statistically significant differences in eye movement between neutral and emotional future thinking, but not between positive and negative future thinking. Our expectation was based on previous research, demonstrating more fixations and saccades but shorter fixation duration during retrieval of emotional than neutral memories, as well similar number of fixations and saccades, fixation duration, duration of saccades, and amplitude of saccades during the retrieval of positive and negative memories (El Haj, Nandrino, et al., 2017).

METHOD

Participants

The study included forty-three undergraduate/graduate students at the University of Nantes (23 females, M_{age} = 21.78 years, SD = 3.72, $M_{education}$ = 13.54 years, SD = 4.44). Informed consent was obtained in accordance with the principles of the Helsinki Declaration. All participants were native French speakers. To evaluate the participants' cognitive performance, we evaluated verbal episodic memory using the test by Grober and Buschke (1987). In this test, participants were invited to retain 16 words, each describing an item belonging to a different semantic category. After a 20 s distraction phase, they were invited to retrieve as many words as possible, the maximum score being 16 points. The mean score of the participants was 12.45 (SD = 2.32).

Besides episodic memory, we evaluated working memory with span tasks in which participants repeated a string of numbers in the same (i.e., forward span) or reverse order (i.e., backward span). The mean score of the participants was 7.11 (SD = 1.65) on the forward span and 5.32 (SD = 1.23) on the backward span. Based on these results, we excluded four participants from the original sample (n = 58) who performed 2 *SD*s below the expected range for their age on the Grober and Buschke (1987) task, and one participant who performed 2 *SD*s below the expected range for his age on the backward span. We also excluded three participants, as they declared history of neurological/psychiatric disorders. We further excluded seven participants due to difficulties with eye movement recording: two participants due to difficulties with calibration, and five participants because of recording quality below 70%. After applying these exclusion criteria, the final sample was 43 participants. This final sample size was determined a priori using *G*Power* (Faul et al., 2007). Calculation was conducted for a repeated-measures analysis of variance (ANOVA) tests (three within-subjects measurements: neutral future thinking condition, positive future thinking condition, and negative future thinking condition), based on 95% power, an estimated probability of making Type I

error as .05, and a medium effect size of 0.25 (Cohen, 1992). In the final sample size, no significant differences were observed regarding gender, χ^2 (1, N = 43) = .21, p = .64.

Procedure

Participants were invited to verbally construct one neutral future event, one positive future event, and one negative future event. During retrieval, the participants wore eye tracking glasses and faced a white wall. For each of the three future events, participants were asked verbally to imagine an event that might reasonably occur in the future, regardless of whether it will occur in the near or distant future. Participants were invited to be precise and specific, that is, the event had to last no more than a day and details had to be provided (e.g., where the event will occur, what they will do during it, who will be present, what their feelings will be). An example of the future events, as imagined by a participant is provided in the appendix. Each of the three future events was cued by one of the following cues: "happy," "sad," and "city," as the latter cue may be considered a neutral cue (El Haj, Nandrino, et al., 2017; Maki et al., 2013). The order of three cues (i.e., the order of the three cued-future events) was randomly counterbalanced across participants. Participants were allocated 2 min to describe each of the three events and the duration was made clear so that the participants could structure the events accordingly. Note that no statistically significant differences were observed regarding the duration of retrieval across the three conditions, $M_{\text{positive future thinking}}$ = 69.22 sec, SD = 16.11, $M_{\text{neutral future thinking}}$ = 66.41 sec, SD = 10.02, $M_{\text{negative future thinking}}$ = 64.32 sec, SD = 12.42, F(2, 126) = 1.52, p = .022.

During future thinking, participants wore eye tracking glasses. These glasses (Pupil Lab) were a remote pupil-tracking system that used infrared illumination with a gaze position accuracy of < 0.1 ° and 200 Hz sampling rate. Recordings were processed with the Pupil Capture software. Prior to each of the three conditions (i.e., neutral, positive, and negative), calibration was made by inviting participants to fixate on a black cross (a 5 × 5 cm cross, printed on an A4 white paper fixated at the wall center). The cross was retained as a single calibration point (and was withdrawn after calibration). Participants were tested individually and the experiment occurred in a quiet room at the psychology department of the University of Nantes. Blinds were closed and the brightness of the room (60-watt fluorescent lamp) was the same in the two conditions to ensure that differences in eye movements were not caused by differences in retinal illumination. Participants were seated in front of a white wall and the distance between the subjects and wall was approximately 30 to 50 cm. Participants were invited not to look outside the wall, but were free to explore all parts of it. The wall displayed no visual stimuli (e.g., drawings, windows). Note that this wall design was different from previous research on eye movement during future thinking (El Haj & Lenoble, 2018) in which participants had to construct future events while looking at a 21 in. screen. Unlike the wall-based design, the screen-based one implies limited visual exploration, as participants have to explore only the (space-limited) screen which may significantly constraint the visual system. Regarding data processing, and as clarified in the Participants section, we excluded participants with poor recording quality. The recording quality considers bias such as looking away from the wall or loss of data.

Dependent Variables

In line with previous research (El Haj & Lenoble, 2018; Lenoble et al., 2019), we calculated the number of fixations, fixation duration, number of saccades, saccade duration, and total amplitude. Fixation and saccade counts referred to the number of fixation or saccades per minute. Note that we applied this ratio because future thinking of several participants ended before the 2 min interval was over. Regarding average fixation and saccade durations, these variables referred to the mean duration of fixation/saccades in milliseconds. The total amplitude size variable referred to the total angle covered by the saccades. When extracting data, we excluded blinks and abnormal saccades (i.e., deviations of saccadic amplitude that exceeded 2 *SD* from the means).

Statistical Analysis

Each dependent variable (i.e., number of fixations, fixation duration, number of saccades, saccade duration, total amplitude, and total duration of recording) was submitted to a repeated-measures ANOVA with the condition (i.e., neutral, positive, and negative future thinking) as a within-subject variable. Statistically significant ANOVAs were followed up by *t* test pairwise comparisons. For *t* tests, we provided effect sizes using Cohen's *d* (Cohen, 1992): 0.20 = small, 0.50 = medium, 0.80 = large. For all tests, the level of significance was set as $p \leq .05$.

RESULTS

Regarding the number of fixations, the analysis showed a statistically significant effect of condition, F(2, 84) = 8.81, p < .001, η^2 = .17. Pairwise comparisons showed fewer number of fixations during neutral than during positive, t(42) = 3.74, p = .001, Cohen's d = .69, and negative future thinking, t(42) = 4.12, p < .001, Cohen's d = .74. No statistically significant differences were observed between positive and negative future thinking, t(42) = .15, p = .81, Cohen's d = .03. Regarding the duration of fixations, the analysis showed a significant effect of condition, F(2, 84) = 5.43, p = .006, η^2 = .12. Pairwise comparisons showed longer fixations during neutral than during positive, t(42) = 2.64, p = .011, Cohen's d = .50, and negative future thinking, t(42) = 2.43, p = .02, Cohen's d = .49. No statistically significant differences were observed between positive and negative future thinking, t(42) = .34, p = .74, Cohen's d = .06. No statistically significant differences were observed between the three conditions regarding the number of saccades, F(2, 84) = .86, p = .49, η^2 = .01, saccade duration F(2, 84) = .50, p = .61, η^2 = .01, total amplitude, F(2, 84) = .40, p = .76, η^2 = .01, or total duration of recording, F(2, 84) = .44, p = .68, η^2 = .01.

DISCUSSION

We investigated eye movement during neutral, positive, and negative future thinking. We found more and shorter fixations during positive

TABLE 1.
Eye Movement Variations and Duration of Recording During Neutral, Positive, and Negative Future Thinking

		Neutral	Positive	Negative
Eye movement	Fixation count per min	58.02 (17.28) $p = .001$	79.56 (29.47) $p = .81$	80.65 (32.95)
	Fixation duration in msec	725.02 (457.68) $p = .011$	505.13 (194.89) $p = .74$	522.33 (245.53)
	Saccade count per min	62.53 (27.90) $p = .11$	69.42 (25.16) $p = .49$	66.53 (24.73)
	Duration of saccades in msec	56.66 (27.54) $p = .10$	53.10 (19.53) $p = .33$	58.59 (29.33)
	Amplitude of saccades in degrees	1580.25 (853.98) $p = .61$	1433.32 (643.32) $p = .35$	1549.91 (792.53)
Duration of recording in msec		82572.53 (27174.35) $p = .62$	80613.12 (32990.35) $p = .63$	78786.12 (25533.62)

Note. Standard deviations are given between brackets; maximum duration of recording was 120 000 msec; the *p* values are provided regarding comparisons with the next condition

and negative emotional thinking than during neutral future thinking. No statistically significant differences were observed between neutral and emotional future thinking or between positive and negative future thinking regarding the number, duration, or amplitude of the saccades.

Regarding the comparison between neutral and emotional future thinking, statistically significant differences were observed between neutral and emotional future thinking for fixations but not for saccades. More specifically, participants fixated longer when imagining neutral than positive or negative future scenarios. Generally speaking, the duration of fixations reflects the allocation of attention to a given stimuli and stimulus complexity, at least as demonstrated by research on visual perception (McConkie, 1983; Sperling & Weichselgartner, 1995). Furthermore, the duration of fixations has been widely considered as a measure of information processing (Zelinsky, 2013). Therefore, short fixations during emotional future thinking may mirror a mental visual exploration involving processing of a less complex visual representation compared with neutral future thinking. These short fixations may also mirror low narrative structure during emotional thinking. The lack of statistical significance regarding the number and duration of fixations between positive and negative future thinking can be attributed to a similar mental visual representation between these two conditions. More specifically, the lack of statistical significance regarding the number and duration of fixations between positive and negative future thinking can be attributed to a similar activation of mental representations. This suggestion is based on the assumption that saccades reflect the attempt by the visual system to find (through saccades) and activate (through fixations) stored mental representations (El Haj et al., 2014).

Eye movement, as observed in our study, can be also attributed to mental imagery. Generally speaking, eye movement during past and future thinking has been attributed to mental imagery required to generate the visual scene of the constructed events (El Haj et al., 2014; El Haj, Nandrino, et al., 2017; Lenoble et al., 2019). The involvement of mental imagery in future thinking has been reported in research demonstrating how imagining future events, especially near compared with distant ones, involves the generation of visual perspective such as seeing the event through one's own eyes (D'Argembeau & Van der Linden, 2004; Hamilton & Cole, 2017; Macrae et al., 2015). Mental imagery involving the construction of internal representations of sensory-perceptual information in the absence of external sensory input has been considered as the main format of mental representations (Conway, 2009). Mental imagery has the capacity to simulate not only the perceptual characteristics, but also the subjective experience of future events, as if they were real (Moulton & Kosslyn, 2009). Taken together, eye movement, as observed during neutral and future thinking, can be attributed to the attempt of the cognitive system to construct an internal representation of the constructed sensory-perceptual information. This construction may be less effortful for emotional than for neutral future thinking, as shorter fixations were observed during emotional than neutral future thinking. However, a similar level of mental imagery seems to be triggered by positive and negative future thinking, as similar eye movement activities were observed between the two emotional conditions in our study. Alternatively, eye movement, as observed during neutral and future thinking, can be attributed to other processes such as mental effort, as emotional future thinking may involve more cognitive load than neutral future thinking. Also, eye movement, as observed during neutral and future thinking, can be attributed to changes in biochemistry that simply drive eye movement activity.

Our findings can be compared with those of previous research on eye movement during emotional past thinking. Like our study, previous research has demonstrated some differences in eye movement between neutral and emotional past thinking, but no differences between positive and negative thinking (El Haj, Nandrino, et al., 2017). These findings demonstrate that both positive and negative past and future thinking trigger similar eye movement activities. Interestingly, these findings demonstrate striking similarities between past and future thinking. Both rely on similar cognitive processes, such as the ability to project oneself in time (Suddendorf, 2010; Tulving, 2002).

Both abilities also emerge approximately at the same time of development (Suddendorf, 2010) and decline in parallel among individuals with acquired amnesia (Klein et al., 2002), depression (Williams et al., 1996), schizophrenia (D'Argembeau et al., 2008) and Alzheimer's disease (Addis et al., 2009; El Haj et al., 2015a, 2015b). Past and future thinking also activate a common neural basis, especially the medial temporal lobes and the hippocampus (Addis et al., 2007; Hassabis et al., 2007; Okuda et al., 2003; Race et al., 2011). Our findings extend this literature by demonstrating that both positive and negative past and future thinking trigger similar eye movement activities.

Limitations

One limitation of our study may be the assessment of only one event for each emotional category as well as the assessment of only one category of negative and positive emotions. It is quite possible, for instance, that the findings would vary if we had used the cue "fear" rather than "sad," or "relief" rather than "happy." Other potential limitations may be the lack of assessment of the complexity of imagined scenarios or the lack of assessment of temporal distance, as near and distant future thinking may differ in terms of complexity of visual representation, and consequently, in terms of eye movements.

However, and regardless of these potential limitations, our study has important implications as it provides new behavioral insight into emotional future thinking and emotion in general.

Venues for Future Research

Our study has several implications for future research on emotional future thinking and emotion in general. For instance, it would be of interest to examine whether retrieval can be characterized by long saccades and short saccades in depression, such that patients with depression may have difficulties in constructing/exploring the visual scene during retrieval. Because negative future-oriented cognition, a main feature of depression, is considered to be involved in the etiology and maintenance of emotional disturbances in this psychiatric condition (Beck et al., 1996), it would be of interest to assess whether negative memories can be indexed by a specific pattern of eye movement. Future research can also evaluate the relationship between eye movement and emotion regulation strategies such as reappraisal and expressive suppression (i.e., suppression of behavioral expression of emotions) in the general population. Whereas reappraisal is associated with efficient regulation and high self-esteem, expressive suppression is associated with avoidance and inhibition of emotional expressivity (Gross & John, 2003). It would be of interest to evaluate whether individuals with high reappraisal strategies tend to fixate more when telling future scenarios to others.

Conclusion

In sum, prior research has been mainly concerned with cognitive and clinical characteristics of future thinking. By evaluating eye movement during future thinking, our study builds on prior research. Moreover, by demonstrating how specific eye movement can be observed during neutral and emotional future thinking, our study provides new behavioral insight into the study of emotional future thinking and emotions in general.

ACKNOWLEDGEMENTS

The authors state no conflict of interest.

DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

REFERENCES

Addis, D. R., Sacchetti, D. C., Ally, B. A., Budson, A. E., & Schacter, D. L. (2009). Episodic simulation of future events is impaired in mild Alzheimer's disease. *Neuropsychologia, 47*(12), 2660–2671. https://doi.org/10.1016/j.neuropsychologia.2009.05.018

Addis, D. R., Wong, A. T., & Schacter, D. L. (2007). Remembering the past and imagining the future: Common and distinct neural substrates during event construction and elaboration. *Neuropsychologia, 45*(7), 1363–1377. https://doi.org/10.1016/j.neuropsychologia.2006.10.016

Barsics, C., Van der Linden, M., & D'Argembeau, A. (2016). Frequency, characteristics, and perceived functions of emotional future thinking in daily life. *The Quarterly Journal of Experimental Psychology, 69*(2), 217–233. https://doi.org/10.1080/17470218.2015.1051560

Baumgartner, H., Pieters, R., & Bagozzi, R. P. (2008). Future-oriented emotions: Conceptualization and behavioral effects. *European Journal of Social Psychology, 38*(4), 685–696. https://doi.org/10.1002/ejsp.467

Beck, A., Steer, R., & Brown, G. (1996). *BDI-II: The Beck Depression Inventory*. The Psychological Corporation.

Berntsen, D., & Bohn, A. (2010). Remembering and forecasting: The relation between autobiographical memory and episodic future thinking. *Memory & Cognition, 38*(3), 265–278. https://doi.org/10.3758/MC.38.3.265

Cohen, J. (1992). Statistical power analysis. *Current Directions in Psychological Science, 1*(3), 98–101. https://doi.org/10.2307/20182143

Conway, M. A. (2009). Episodic memories. *Neuropsychologia, 47*(11), 2305–2313. https://doi.org/10.1016/j.neuropsychologia.2009.02.003

D'Argembeau, A., Raffard, S., & Van der Linden, M. (2008). Remembering the past and imagining the future in schizophrenia. *Journal of Abnormal Psychology, 117*(1), 247–251. https://doi.org/10.1037/0021-843X.117.1.247

D'Argembeau, A., Renaud, O., & Van der Linden, M. (2011). Frequency, characteristics and functions of future-oriented thoughts in daily life. *Applied Cognitive Psychology, 25*(1), 96–103. https://doi.org/10.1002/acp.1647

D'Argembeau, A., & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition, 13*(4), 844–858. https://doi.

org/10.1016/j.concog.2004.07.007

D'Argembeau, A., & Van der Linden, M. (2012). Predicting the phenomenology of episodic future thoughts. *Consciousness and Cognition, 21*(3), 1198–1206. https://doi.org/10.1016/j.concog.2012.05.004

de Vito, S., Neroni, M. A., Gamboz, N., Della Sala, S., & Brandimonte, M. A. (2015). Desirable and undesirable future thoughts call for different scene construction processes. *The Quarterly Journal of Experimental Psychology, 68*(1), 75–82. https://doi.org/10.1080/17470218.2014.937448

El Haj, M., Antoine, P., & Kapogiannis, D. (2015a). Flexibility decline contributes to similarity of past and future thinking in Alzheimer's disease. *Hippocampus, 25*(11), 1447–1455. https://doi.org/10.1002/hipo.22465

El Haj, M., Antoine, P., & Kapogiannis, D. (2015b). Similarity between remembering the past and imagining the future in Alzheimer's disease: Implication of episodic memory. *Neuropsychologia, 66*, 119–125. https://doi.org/10.1016/j.neuropsychologia.2014.11.015

El Haj, M., Antoine, P., & Nandrino, J. L. (2017). Facial expressions triggered by imagining the future. *Journal of Integrative Neuroscience, 16*(4), 483–492. https://doi.org/10.3233/JIN-170030

El Haj, M., Delerue, C., Omigie, D., Antoine, P., Nandrino, J. L., & Boucart, M. (2014). Autobiographical recall triggers visual exploration. *Journal of Eye Movement Research, 7*(5), 1–7. https://doi.org/https://doi.org/10.16910/jemr.7.5.1

El Haj, M., & Lenoble, Q. (2018). Eying the future: Eye movement in past and future thinking. *Cortex, 105*, 97–103. https://doi.org/https://doi.org/10.1016/j.cortex.2017.05.024

El Haj, M., Nandrino, J. L., Antoine, P., Boucart, M., & Lenoble, Q. (2017). Eye movement during retrieval of emotional autobiographical memories. *Acta Psycholol gica, 174*, 54–58. https://doi.org/10.1016/j.actpsy.2017.02.002

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods, 39*(2), 175–191. https://doi.org/10.3758/BF03193146

Finnbogadóttir, H., & Berntsen, D. (2013). Involuntary future projections are as frequent as involuntary memories, but more positive. *Consciousness and Cognition, 22*(1), 272–280. https://doi.org/10.1016/j.concog.2012.06.014

Grober, E., & Buschke, H. (1987). Genuine memory deficits in dementia. *Developmental Neuropsychology, 3*(1), 13–36. https://doi.org/10.1080/87565648709540361

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85*(2), 348–362. https://doi.org/10.1037/0022-3514.85.2.348

Hamilton, J., & Cole, S. N. (2017). Imagining possible selves across time: Characteristics of self-images and episodic thoughts. *Consciousness and Cognition, 52*, 9–20. https://doi.org/10.1016/j.concog.2017.04.015

Hassabis, D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences, 104*(5), 1726-1731. https://doi.org/10.1073/pnas.0610561104

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330*(6006), 932–932. https://doi.org/10.1126/science.1192439

Klein, S. B., Loftus, J., & Kihlstrom, J. F. (2002). Memory and temporal experience: The effects of episodic memory loss on an amnesic patient's ability to remember the past and imagine the future. *Social Cognition, 20*(5), 353–379.

Lenoble, Q., Janssen, S. M. J., & El Haj, M. (2019). Don't stare, unless you don't want to remember: Maintaining fixation compromises autobiographical memory retrieval. *Memory, 27*(2), 231–238. https://doi.org/10.1080/09658211.2018.1501068

Macrae, C. N., Mitchell, J. P., Tait, K. A., McNamara, D. L., Golubickis, M., Topalidis, P. P., & Christian, B. M. (2015). Turning I into me: Imagining your future self. *Consciousness and Cognition, 37*, 207–213. https://doi.org/10.1016/j.concog.2015.09.009

Maki, Y., Janssen, S. M. J., Uemiya, A., & Naka, M. (2013). The phenomenology and temporal distributions of autobiographical memories elicited with emotional and neutral cue words. *Memory, 21*(3), 286–300. https://doi.org/10.1080/09658211.2012.725739

McConkie, G. W. (1983). Eye movements and perception during reading. In K. Rayner (Ed.), *Eye movements in reading: Perceptual and language processes* (pp. 65–96). Academic Press.

Moulton, S. T., & Kosslyn, S. M. (2009). Imagining predictions: mental imagery as mental emulation. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1521), 1273–1280. https://doi.org/doi:10.1098/rstb.2008.0314

Newby-Clark, I. R., & Ross, M. (2003). Conceiving the past and future. *Personality and Social Psychology Bulletin, 29*(7), 807–818. https://doi.org/10.1177/0146167203029007001

Okuda, J., Fujii, T., Ohtake, H., Tsukiura, T., Tanji, K., Suzuki, K., Kawashima, R., Fukuda, H., Itoh, M., & Yamadori, A. (2003). Thinking of the future and past: the roles of the frontal pole and the medial temporal lobes. *NeuroImage, 19*(4), 1369–1380. https://doi.org/10.1016/S1053-8119(03)00179-4

Race, E., Keane, M. M., & Verfaellie, M. (2011). Medial temporal lobe damage causes deficits in episodic memory and episodic future thinking not attributable to deficits in narrative construction. *Journal of Neuroscience, 31*(28), 10262–10269. https://doi.org/10.1523/JNEUROSCI.1145-11.2011

Rasmussen, A. S., & Berntsen, D. (2013). The reality of the past versus the ideality of the future: emotional valence and functional differences between past and future mental time travel. *Memory & Cognition, 41*(2), 187–200. https://doi.org/10.3758/s13421-012-0260-y

Schacter, D. L., Benoit, R. G., & Szpunar, K. K. (2017). Episodic future thinking: Mechanisms and functions. *Current Opinion in Behavioral Sciences, 17*, 41–50. https://doi.org/10.1016/j.cobeha.2017.06.002

Sharot, T., Riccardi, A. M., Raio, C. M., & Phelps, E. A. (2007). Neural mechanisms mediating optimism bias. *Nature, 450*(7166), 102–105.

https://doi.org/10.1038/nature06280

Sperling, G., & Weichselgartner, E. (1995). Episodic theory of the dynamics of spatial attention. *Psychological Review, 102*(3), 503–532. https://doi.org/10.1037/0033-295X.102.3.503

Stawarczyk, D., & D'Argembeau, A. (2015). Neural correlates of personal goal processing during episodic future thinking and mind-wandering: An ALE meta-analysis. *Human Brain Mapping, 36*(8), 2928–2947. https://doi.org/10.1002/hbm.22818

Suddendorf, T. (2010). Episodic memory versus episodic foresight: Similarities and differences. *Wiley Interdisciplinary Reviews: Cognitive Science, 1*(1), 99–107.

Suddendorf, T., & Busby, J. (2005). Making decisions with the future in mind: Developmental and comparative identification of mental time travel. *Learning and Motivation, 36*(2), 110–125. http://dx.doi.org/10.1016/j.lmot.2005.02.010

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53*, 1–25. https://doi.org/10.1146/annurev.psych.53.100901.135114

Williams, J. M., Ellis, N. C., Tyers, C., Healy, H., Rose, G., & MacLeod, A. K. (1996). The specificity of autobiographical memory and imageability of the future. *Memory & Cognition, 24*(1), 116–125. http://www.ncbi.nlm.nih.gov/pubmed/8822164

Yang, Z. Y., Wang, S. K., Li, Y., Wang, Y., Wang, Y. M., Zhou, H. Y., Cai, X. L., Cheung, E. F. C., Shum, D. H. K., Ongur, D., & Chan, R. C. K. (2019). Neural correlates of prospection impairments in schizophrenia: Evidence from voxel-based morphometry analysis. *Psychiatry Research: Neuroimaging, 293*, 110987. https://doi.org/10.1016/j.pscychresns.2019.110987

Zelinsky, G. J. (2013). Understanding scene understanding. *Frontiers in Psychology, 4*, 954. https://doi.org/10.3389/fpsyg.2013.00954

RECEIVED 23.09.2022 | ACCEPTED 21.02.2023

APPENDIX

An example of the future thinking, as imagined by a participant to the cue "happy":

"This summer I would like to travel for a couple of weeks to the Caribbean islands…just after the exams….Perhaps next year as I should work and earn some money to pay my travel…I can already imagine myself sitting on a beautiful Caribbean beach…A quit beach with no crowds…I would just like to smell the salty sea and listen as the waves lap the beach with palm trees swaying in the wind…what else?... I am imagining seeing these amazing waters with my own eyes…almost perfection…this would be my happy place."