

**Left lateralization in autobiographical memory: An fMRI study using the expert
archival paradigm**

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Abstract

In brain-imaging and behavioural research, studies of autobiographical memory have higher ecological validity than controlled laboratory memory studies. However, they also have less controllability over the variables investigated. Here we present a novel technique—the expert archival paradigm—that increases controllability while maintaining ecological validity. Stimuli were created from games played by two international-level chess masters. We then asked these two players to perform a memory task with stimuli generated from their own games and stimuli generated from other players' games while they were scanned using fMRI. We found a left lateralised pattern of brain activity which was very similar in both masters. The brain areas activated were the left temporo-parietal junction and left frontal areas. The expert archival paradigm has the advantage of not requiring an interview to assess the participants' autobiographical memories, and affords the possibility of measuring their accuracy of remembering as well as their brain activity related to remote and recent memories. It can also be used in any field of expertise, including arts, sciences and sports, in which archival data are available.

Keywords: autobiographical memory - experimental paradigm - fMRI - expertise - lateralisation.

Left lateralization in autobiographical memory: An fMRI study using the expert archival paradigm

Autobiographical memory is the memory for events that have occurred in one's own life (Conway & Pleydell-Pearce, 2000). It has episodic memory components (Tulving, Kapur, Craik, Moscovitch, & Houle, 1994) and also includes information devoid of contextual information of space and time, such as personal facts (Maguire & Mummery, 1999). Conway and Pleydell-Pearce (2000) proposed that autobiographical memories are substantiated via a long-term memory knowledge base which contains life-time periods, general events and event-specific knowledge, and a working self. The knowledge base and the working self can work independently or together; when they work together, they transiently form a self-memory system that allows the remembering of autobiographical memories. They also suggested that remembering can occur with active participation of the self (generative retrieval) or without it (automatic retrieval).

Conway and Pleydell-Pearce's (2000) model of autobiographical memory makes predictions about the brain location of autobiographical memory components and processes. It suggests that when individuals engage in generative retrieval, activation of the left frontal lobe followed by bilateral activation of posterior temporal, parietal and occipital areas should be observed. This would reflect the activity of the working self (left frontal lobe), actively engaged in the activation of the knowledge base (posterior areas). This prediction received strong support from EEG studies (Conway, Pleydell-Pearce, & Whitecross, 2001; Conway, Pleydell-Pearce, & Whitecross, & Sharpe, 2003) and fMRI or PET studies (Cabeza et al., 2004; Conway et al., 1999; Levine et al., 2004; Gilboa, Winocur, Grady, Hevenor, & Moscovitch,

2004; Maguire & Mummery, 1999; Maguire & Frith, 2003; Piefke, Weiss, Zilles, Markowitsch, & Fink, 2003; but see Fink et al., 1996).

Although the specific activated regions varied across these fMRI and PET studies, two clear patterns emerged: the activations in the frontal lobe were more left lateralized (e.g., Cabeza et al., 2004, Conway et al., 1999, Conway et al., 2001, Conway et al., 2003, Gilboa et al., 2004; Levine et al., 2004; Maguire et al., 2000, Piefke et al., 2003) and the left temporo-parietal junction (BA 39, including inferior parts of BA40) was activated in several studies (e.g., Conway et al., 1999, Levine et al., 2004, Gilboa et al., 2004, Maguire & Mummery, 1999, Maguire, Mummery, & Buchel, 2000).

One possible reason for the existence of differences between these studies may be methodological problems related to brain imaging of autobiographical memory (see Maguire, 2001). Autobiographical memory tasks have higher ecological validity (Neisser, 1976) than typical laboratory memory tasks; however, as a consequence, they also have lower controllability. Finding tasks that combine ecological validity with controllability would be an ideal methodological achievement. The problem of controllability in behavioural autobiographical memory tasks is compounded when one wants to perform neuroimaging studies. Two standard autobiographical memory techniques—the autobiographical memory interview (Kopelman, Wilson, & Baddeley, 1990) and the Crovitz' (Crovitz & Schiffman, 1974) cue-word task—have some difficulties for brain imaging purposes. Exposing participants to an interview before scanning may reinstate the old memories at the time of the interview (see Maguire 2001; Cabeza et al., 2004). As a consequence, the pattern of brain activity in the scanning session may reflect the temporal and spatial context of the interview rather than the temporal and spatial context of the moment when the memory was

originally stored. When performing the cue-word task, participants sometimes do not generate any memory (see Maguire, 2001); as a result, the brain areas expected to be active during a trial would not be activated.

Recently, brain-imaging researchers have developed techniques in order to increase the controllability in autobiographical memory tasks without losing the ecological validity. Levine et al. (2004) had participants record diaries for several months and then the experimenter selectively chose some of the recordings to use in the scanning session. Cabeza et al. (2004) developed the photo paradigm in which university students took photos of several places of the campus and in the scanning session they saw photos taken by them and by others. These techniques are useful when one wants to investigate recent memories, but not for studying memories that participants had encoded years before the beginning of the experiment. Finally, Gilboa et al. (2004) used personal photographs that were obtained from relatives and friends. This approach had a number of advantages: the photographs had previously rarely or never been seen by the participants; the age of the autobiographical memories could be studied using a distribution of events that was ecologically valid; the vividness with which the photographs were remembered varied; and there was no need to re-activate and re-encode memories prior to the scanning sessions.

The aim of this article is to propose an alternative research tool for brain imaging of autobiographical memories. This tool, which has been successfully used for studying cognitive processes in domains such as chess, music, and science, is to recruit experts, and then to ask them to perform tasks from their domain of expertise. We have used this technique to study problem solving (Campitelli & Gobet, 2004; Gobet, 1998), imagery (Campitelli & Gobet, 2005), perception (De Groot & Gobet, 1996), memory (Gobet & Simon, 1996,ab), development (Gobet & Campitelli, 2007),

the brain correlates of expert memory (Campitelli, Gobet, Head, Buckley, & Parker, in press), and other psychological phenomena (see Gobet et al., 2004 for a review).

The domain of expertise most widely used has been chess (see Charness, 1992, for the impact of chess in cognitive psychology). Chess has several advantages that make it a powerful task to study cognitive processes. First, it is a complex game in which many cognitive processes are involved. Second, the existence of an international rating scale affords the possibility for researchers to know the level of expertise of their participants with precision. Third, it is a very controllable environment (a board with 64 squares and 32 pieces) in which innumerable meaningful stimuli can be created. Fourth, given that chessplayers study and play chess using computers, performing chess tasks whilst looking at a computer screen is an ecological task for them. Fifth, there exist databases with millions of games from which stimuli can be created.

We made use of the fifth advantage to develop a novel experimental paradigm—the expert archival paradigm. We recruited two international-level chessplayers and created a set of stimuli using their own games, which were available in the Chessbase database (Chessbase Gmbh, Hamburg). We also created stimuli using games of other international-level players. We scanned the players while they were performing a memory task with both their own games and other players' games and compared the brain activity of these two conditions. The advantage of the expert archival paradigm is that we created stimuli that would trigger autobiographical memories without interviewing the participants before the experiment. Moreover, we were able to compare the brain activity of recent memories with more remote memories by creating stimuli that came from recent games and from old games.

Finally, we were able to measure the accuracy of autobiographical memory using both recall and recognition tasks.

Where does this novel paradigm stand in the continuum between laboratory memory experiments and everyday-autobiographical memory for personal events during life-span? Although it was carried out in the laboratory, we claim this paradigm stands closer to the autobiographical end, for the following reasons: we used meaningful material; we used material previously experienced by the participants; this material triggered participants' personal experiences in the past; and the task of seeing chess stimuli projected on a screen is quite similar to the way participants study chess everyday. The aim of this study was to investigate whether the pattern that emerged from previous studies—left lateralisation of activity in the frontal lobe and activation of the left temporo-parietal junction—can be replicated with the use of a novel paradigm that enhances controllability.

Methods

Participants

Two chess players took part of this experiment: a grandmaster (GM) with 2550 ELO¹ who was 21 years of age, and an international master (IM) with 2500 ELO who was 22 years of age. Both of them were right-handed and signed an informed consent and a safety form. Ethical regulations of the School of Psychology ethical committee and of the Sir Peter Mansfield Magnetic Resonance Centre, both of the University of Nottingham, were followed in the experiment.

Stimuli

Once the participants agreed to take part in the experiment, we searched in Chessbase for games that they had played in official tournaments. With these games 67 stimuli were generated for GM and 66 for IM. This type of stimuli was called “own” (OW). The stimuli consisted of middle-game positions with 26 +/-1 pieces on the board which were displayed on a screen at a 16° x 16° visual angle. We generated stimuli of three different time periods: “recent”—games played in the current year, “intermediate”—games played 2 or 3 years ago, and “remote”— games played 4 or 5 years ago. The colour with which the players played the game and its result (win or lost) were counterbalanced for each subject. For GM there were 20 recent games, 23 intermediate games, and 24 remote games; for IM there were 22 recent games, 20 intermediate games, and 24 remote games. Twenty four games played by grandmasters other than the participants (and unknown to the participants) were also selected and one stimulus of a board position with 26 +/-1 pieces was generated from each game. These stimuli were called “others” (OT). We chose middle-game positions (both for OW and OT) in order to have OT positions that were similar to OW positions in complexity. This would not have been possible with opening positions. Finally, a control stimulus (CO) was generated by selecting a chess position with the same visual characteristics as the positions in the OW and OT conditions, cutting it in small bits, and having these bits randomly rearranged (see Figure 1). Following this procedure, the stimulus had the same perceptual attributes as the positions in the other two conditions, but it was absolutely meaningless. This stimulus was presented 24 times.

Procedure

During the scanning session GM and IM had 115 and 114 blocks, respectively. For GM there were 20 OW-recent blocks, 23 OW-intermediate blocks, 24 OW-remote blocks, 24 OT blocks and 24 control blocks. For IM there were 22 OW-recent blocks, 20 OW-intermediate blocks, 24 OW-remote blocks, 24 OT blocks and 24 control blocks. Each block started with a fixation cross presented for 13 s and followed by either an OW position, an OT position or the CO stimulus (in all the cases, the stimulus was presented for 5 s). The order of the OW, OT and CO blocks was pseudo-randomised so that two OT or CO blocks did not occur one after the other.

Players were told that at some time after the scanning session they would take part in a recall session in which they would have to fill in a form with the games that they were able to remember, indicating opponent, year, tournament, result and next move. They were also told that, after the recall session, they would take part in a recognition-ownership session with OW and OT positions in which they would be required to determine two things for each position presented: whether the position had been presented in the scanning session and whether it was an OW or OT position. Therefore, during the scanning session the players had to keep a record of each position (except the CO stimulus) in order to perform well in the recognition task. In addition, they had to encode each position as OW or OT in order to perform well in the ownership task. Moreover, in the case of OW positions, they had to retrieve the relevant information in order to perform well in the recall task that had to be performed before the recognition task. In the CO blocks participants were asked to view the stimuli passively and not to close their eyes.

The recall session took place 4 hours after the scanning session and the recognition-ownership session was 1 hour after starting the recall session. No time

limit was given for any of these sessions. We chose a four-hour delayed recall test in order to encourage the masters to retrieve as much autobiographical information as possible during the presentation of the OW positions. Being aware of the length of this delay, they knew that it was a difficult task requiring maximum concentration. In the recognition-ownership session all the positions (OW and OT, but not CO) presented in the scanner were shown again; in addition, 24 new OT positions for both players and 63 new OW positions, for GM, and 61 new OW positions, for IM, were presented. In total, GM saw 178 positions (67 OW-old, 24 OT-old, 63 OW-new and 24 OT-new), and IM saw 175 positions (66 OW-old, 24 OT-old, 61 OW-new and 24 OT-new) in the recognition-ownership session.

The rationale for this experimental procedure was that, in the scanning session, the OW and OT blocks would require the same encoding processes, but the OW blocks would also require access to autobiographical memories. We preferred avoiding an overt task during the scanning session for three reasons. First, asking the players to perform a recognition-ownership test immediately after the presentation of an OW position would precluded the possibility of carrying out a recall test. Second, performing a recognition task requires extra-time in the scanner. Since we were interested in the autobiographical memories that the presentation of an OW would trigger and not in recognition *per se*, we preferred to use the scanning time only with the presentation phase of the task. Third, although it is a common practice in fMRI studies to subtract the activation due to finger movements of a control task from that of an experimental task, we felt it preferable to avoid potentially confounding variables (in our case, finger movements) than to control for them.

fMRI procedure

The experiment was carried out in the University of Nottingham Magnetic Resonance Centre in a 3T scanner. The functional images were T2* weighted Echo-Planar images (EPIs) with a matrix size of 64 x 64 voxels. The voxel size was 3 mm x 3 mm in-plane, and the slice thickness was 9 mm. Twenty-two functional coronal slices were obtained per volume; the TR was 3 s and the speed of slice acquisition was 136 ms per slice. Standard analyses were carried out using Statistical Parametric Mapping (SPM 99) software (Wellcome Department of Cognitive Neurology, London, UK), including realignment, normalisation and smoothing. In the latter case, a kernel of 12 x 12 x 12 mm was used.

Statistical analysis

The one-trial blocks were modelled as a box-car function convolved with the hemodynamic response function. The advantage of this design was that it possessed the statistical power of the blocked designs and all the good features of event-related designs. We carried out the following contrasts of interest: OW (all types) > CO, OT > CO and OW (all types) > OT. The first two contrasts gave information about brain activity of the encoding phase of the memory task, with the subtraction of visual aspects of the control task. The critical contrast was OW > OT, which gave information about the retrieval of autobiographical memories during the scanning session. Within the OW condition, we also compared the brain activity between games of different periods (new, intermediate and remote). In the contrasts OW > CO and OT > CO, and in the contrasts of the age of the games, we used a significance value of $p < 0.05$ (corrected). In the contrast OW > OT, since we had a clear prediction of finding activation in the left hemisphere, we used a significance level of $p < 0.001$ (uncorrected) (see Cabeza et al., 2004, for a similar approach).

Results

Behavioural data

In the recall task, GM gave correct information about the tournament, the opponent, the year and the result in 83.6% of the positions shown during the scanning session, whereas IM performed at 69.7%. In both cases, there were no errors. GM and IM remembered the correct following move in 46.3% and 12.1% of the positions, respectively. In the recognition task, GM correctly recognized as previously seen or new 99.2% of the positions in OW and 93.7% in OT (mean 96.4%). The performance of IM was similar: 96.1% in OW, 89.6% in OT (mean 92.8%). GM assigned ownership correctly to 97.2% of the positions and IM performed at 89.1% correct. These high scores in recall and almost perfect scores in recognition show that both participants were indeed paying attention to the presented positions during the scanning session, and thus performing the task as requested. Immediately after the scanning session (i.e., almost four hours before the recall and recognition-ownership sessions), both players commented to the experimenter that most of the OW positions made them remember aspects of the situation of the game, such as the face of the opponent and the venue of the tournament and, in some cases, emotional states during the game or the tournament.

fMRI data

We found no differences among the three age conditions. Table 1 shows the Talairach coordinates of the brain areas activated in the other three contrasts (OW > CO, OT > CO and OW > OT) for GM, and Table 2 displays the same information for IM.

The most important contrast of this study is OW > OT, for it gives information about the brain areas involved in autobiographical memory. Essentially, both conditions have the same visual information, and they also share the same chess semantics. They only differ in that the condition OW may activate autobiographical memories that the participants have of their own experiences, which may not happen in the condition OT. This contrast showed a remarkably similar pattern in both players, which included the left frontal lobe and a posterior area in the temporo-parietal junction. In GM this was somewhat more dorsal to that of IM, including posterior temporal and parietal areas in the former, and inferior parietal and superior parietal in the latter. Figure 2 displays the brain activations in a template 3D brain.

As other task demands are present, autobiographical memory processes do not occur in isolation during the task. In addition, the masters have to process the chess stimuli, recognize them and encode them as members of the “seen” stimulus and as either an OW or OT stimulus. The brain activity due to these processes was captured in the other two contrasts. CO only required that the subjects looked at a stimulus that matched in colour with OW and OT, but they did not have any meaning to encode; furthermore, in CO there was no memory task. Hence, both OW > CO and OT > CO show the brain activity due to the processes mentioned above, while controlling for the visual aspects of the stimuli. Most of the activations in the OW > CO contrast were bilateral and were the same in both players, with the only difference being the number of voxels activated. The activity was concentrated bilaterally in the following areas: middle occipital gyri, superior parietal lobes, posterior cingulate, medial temporal areas (parahippocampal gyri and fusiform gyri) and inferior frontal gyri. In OT > CO, the majority of the activations were also bilaterally distributed in both players. In GM the middle occipital gyri and medial temporal areas (parahippocampal

and fusiform gyri) contained most of the total activity. IM had activations in the two regions mentioned above and also the superior parietal lobules and inferior frontal gyri.

Discussion

Following Nichelli et al's. (1994) pioneering brain imaging study with chess players, we conducted an fMRI study in order to investigate autobiographical memory. We found a strong left lateralisation of brain activity in the frontal lobe in a contrast that measured autobiographical memory, as well as activity in the left temporo-parietal junction.

The strength of our paradigm is that it makes it possible to obtain specific information about the time, location, and context of the stimuli used in the memory test. Our paradigm also rules out that procedural rules or semantic scripts were used in the positions that the participants had played and not in the control positions, because, by selection, the only difference between the two types of positions was whether they had been played by a participant—whether they belonged to his autobiographical memory. We acknowledge the possibility that the memories elicited by the stimulus positions had been remembered between the time they first occurred and the time they were presented in the scanner; but of course, the same possibility applies to the types of stimuli used in other studies.

The resemblance between the results of this study and those of Conway et al. (1999) is outstanding. Both studies showed two highly differentiated regions activated: one posterior region at or near the left temporo-parietal junction (BA 39) and an anterior pattern of a number of left frontal areas. Activation of the left temporo-parietal junction was also found in other studies (e.g., Levine et al., 2004;

Gilboa et al., 2004; Maguire & Mummery, 1999; Maguire et al., 2000). A left lateralised pattern of brain activity in the frontal lobe was found in several autobiographical memory studies (e.g., Cabeza et al., 2004, Conway et al., 2001, 2003; Gilboa et al., 2004; Levine et al., 2004; Maguire & Mummery, 1999; Maguire et al., 2000; Piefke et al., 2003). Some studies found activations in either the left, the right, or both temporal lobes (e.g., Cabeza et al., 2004, Conway et al., 2001, Fink et al., 1996; Levine et al., 2004; Gilboa et al., 2004; Maguire and Mummery, 1999; Maguire et al., 2000, Maguire and Frith, 2003; Markowitsch et al., 2003; Piefke et al., 2003; Niki & Luo, 2002).

The pattern of activation in the frontal cortex differed somewhat to what had been found in previous studies. The contrast OW > OT showed greater activation in left lateral and anterior areas of the prefrontal cortex, a result not usually found in autobiographical memory studies (see Gilboa, 2004, for a review of prefrontal activations in autobiographical and episodic memory studies). Burgess, Maguire, Spiers and O'Keefe (2001) claimed that the activation they found in dorsolateral and anterior regions of the prefrontal cortex were due to the similar nature of events used in their study. This may have caused interference during retrieval and in turn increase the activation of those areas. In our study the stimuli and events to retrieve were also similar in nature (information of opponents, chess tournament venues). The retrieval of these data for the OW stimuli may have caused interference and, in turn, additional activation of the above-mentioned areas.

Regarding the age of the memories, and in line with Conway et al. (1999), we did not find any differences between recent memories (current year) and remote memories (up to 6 years old). In contrast, some studies have found differences between memories of different years (e.g., Niki & Luo, 2002; Maguire, Henson,

Mummery, & Frith, 2001). One explanation why we did not find differences in brain activity due to the age of the games is that the most recent games were played 8 months before the experiment. One possible improvement in our paradigm would be to ask the masters to play some games some days before the experiment and generate stimuli with positions of those games in order to use more recent memories.

How well do our results support Conway and Pleydell-Pearce's (2000) model of autobiographical memory? The prediction that there would be activation in the left prefrontal cortex was supported by our data. We found brain activity in both the ventrolateral and dorsolateral prefrontal cortex, both of which are known to be involved in working memory (Cabeza & Nyberg, 2000). This is in line with Conway and Pleydell-Pearce's (2000) hypothesis that the generation of autobiographical memories starts with the activity of the working-self, which they hypothesize is associated with Baddeley's (1986) concept of working memory. The prediction of the model that there would be brain activity in posterior areas of the brain, reflecting the activation of the knowledge base, was partially supported by our results. We found activation in the left temporo-parietal junction and surrounding areas but not in right posterior areas of the brain. In fact, our results are very similar to those of Conway et al. (1999). Regarding the temporo-parietal junction, since it has been involved in the interpretation of others' movements, goals, and intentions (Frith & Frith, 1999), Levine et al. (2004) suggested that activation in this area in autobiographical memory studies might be attributed to mental imagery of past movements and behaviours. This can be related to the template theory of expertise (Gobet & Simon, 1996b), which states that chessplayers have a knowledge base of familiar configurations of pieces stored in long-term memory and that these configurations are linked to moves. Moreover, Gobet and Simon (1996b) proposed that when players perceive a chess

position they recognise the configurations and the linked moves are automatically activated. Given that in the present study this would apply to both OW and OT positions, it might have been the case that the games of the players generated more vivid images of the moves and that would be the explanation of the activation in the left temporo-parietal junction.

Overall, our results are in agreement with previous reviews in neuroimaging of autobiographical memory that found a clear tendency to find a left lateralised activation (Maguire, 2001; Levine, 2004). However, the left hemisphere does not work in isolation. The contrast OW > CO showed extended activation in the right hemisphere both in frontal and posterior areas. The CO stimuli matched in colour the OW stimuli but the meaningfulness was destroyed; moreover, since the control task required only passive viewing, no encoding processes were necessary. It may be the case that the activation of the right hemisphere is necessary (but not sufficient) to perform autobiographical memory tasks as well as other types of memory encoding tasks (note that the OT > CO contrast, which is not related to autobiographical memory, showed activity in similar areas to that seen in the OW > CO contrast). This may explain why, in autobiographical memory studies of patients with brain damage, the data suggest that the right hemisphere is important in performing autobiographical memory tasks (see Kopelman & Kapur, 2001; see also Greenberg & Rubin, 2003, for a different explanation). Incidentally, the choice of two control tasks in our study—one for the control of non-autobiographical memory processes and the other for the control of perceptual processes—allowed us to discriminate between activations that are only autobiographical and activations that are necessary for performing the task, but that would also be used for a non-autobiographical memory task (see Maguire, 2001, for a discussion of the importance of correct control tasks).

We acknowledge two possible criticisms to this study. First, we used only two participants. The goal of this study was to show that the expert archival paradigm, which we believe has very interesting features, produces similar results to experiments done with other experimental paradigms. Therefore, the goal is achieved if the autobiographical memory community gets to know this paradigm and carries out experiments that overcome this shortcoming.

Second, we did not use “normal” individuals. It can be argued that the memory of international-level chessplayers differs from that of “normal” people. However, there are two reasons why we are sure this is not the case. First, the intra-individual control task we used (OT) allowed us to subtract every supposedly “beyond normal” process, because the “chess memory” would have worked in the OT condition as well. Second, there is a unanimous agreement in the chess psychology literature that chessplayers do not have a better memory than non-chessplayers: the working memory limits apply to them as well (Waters, Gobet, & Leyden, 2002). The main difference is the quantity of chess patterns stored in long-term memory (Gobet & Simon, 1996b). However, we acknowledge a difference between outstanding chessplayers and non-chessplayers: they have a quick access to stored long-term memory patterns (Gobet & Simon, 1996b). This is why the players did not need more than 5 s to have a rich recollection of their autobiographical memories during scanning, which in the case of normal participants usually requires much more time (Conway & Pleydell-Pearce, 2000). In other words, the difference between chessplayers’ memory and that of non-chessplayers is quantitative and not qualitative; that is why we claim that the results provided by this paradigm are generalizable to normal autobiographical memory (the resemblance of our results with those of other studies gives credit to this claim).

Using a novel experimental paradigm, we have shown that a network of brain areas in the left hemisphere is implicated in autobiographical memory processes. The expert archival paradigm we have presented here, which can be extended to any field of expertise (including science, sports and arts) in which visual archival data are available, maintains the ecological validity of the field of autobiographical memory research and increases the controllability of the variables investigated. This paradigm offers a promising avenue for future research in autobiographical memory.

References

- Baddeley, A. D. *Working memory*. (1986). Oxford, UK: Clarendon Press.
- Burgess, N., Maguire, E. A., Spiers, H. J., & O'Keefe, J. (2001). A temporoparietal and prefrontal network for retrieving the spatial context of lifelike events. *NeuroImage, 14*, 439-453.
- Cabeza, R., & Nyberg, L. (2000). Imaging cognition II: An empirical review of 275 PET and fMRI studies. *Journal of Cognitive Neuroscience, 12*, 1-47.
- Cabeza R. , Prince, S. E., Daselaar, S. M., Greenberg, D. L., Budde, M., Dolcos, F., Labar, K. S., & Rubin, D. C. (2004). Brain activity during episodic retrieval of autobiographical and laboratory events: An fMRI study using a novel photo paradigm. *Journal of Cognitive Neuroscience, 16*, 1583-1594.
- Campitelli, G., & Gobet, F. (2004). Adaptive expert decision making: Skilled chess players search more and deeper. *Journal of the International Computer Games Association, 27*, 209-216.
- Campitelli, G., & Gobet, F. (2005). The mind's eye in blindfold chess. *European Journal of Cognitive Psychology, 17*, 23-45.
- Campitelli, G., Gobet, F., Head, K., Buckley, M., & Parker, A. (in press). Brain localisation of memory chunks in chessplayers. *International Journal of Neuroscience*.
- Charness, N. (1992). The impact of chess research in cognitive science. *Psychological Research, 54*, 4-9.
- Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review, 107*, 261-288.

- Conway, M. A., Pleydell-Pearce, C. W., & Whitecross, S. E. (2001). The neuroanatomy of autobiographical memory: A slow cortical potential study of autobiographical memory retrieval. *Journal of Memory and Language*, *45*, 493-524.
- Conway, M. A., Pleydell-Pearce, C. W., Whitecross, S. E., & Sharpe, H. (2003). Neurophysiological correlates of memory for experienced and imagined events. *Neuropsychologia*, *41*, 334-340.
- Conway, M. A., Turk, D. J., Miller, S. L., Logan, J., Nebes, R. D., Cidis Meltzer, C., & Becker, J. T. (1999). A positron emission tomography (PET) study of autobiographical memory retrieval, *Memory*, *7*, 679-702.
- Crovitz, H. H., & Schiffman, H. (1974). Frequency of episodic memories as a function of their age. *Bulletin of the Psychonomic Society*, *4*, 517-518.
- De Groot, A. D., & Gobet F. (1996). *Perception and memory in chess*. Assen: Van Gorcum,.
- Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W. D. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. *The Journal of Neuroscience*, *16*, 4275-4282.
- Frith, C. D., & Frith U. (1999). Interacting minds—A biological basis. *Science*, *286*, 1692-1695.
- Gilboa, A. (2004). Autobiographical and episodic memory—one and the same? Evidence from prefrontal activation in neuroimaging studies. *Neuropsychologia*, *42*, 1336-1349.

- Gilboa, A., Winocur, G., Grady C. L., Hevenor, S. J., & Moscovitch, M. (2004). Remembering our past: Functional neuroanatomy of recollection of recent and very remote personal events. *Cerebral Cortex*, *14*, 1214-1225.
- Gobet, F. (1998). Chess players' thinking revisited. *Swiss Journal of Psychology*, *57*, 18-32.
- Gobet, F., & Campitelli, G. (2007). The role of domain-specific practice, handedness and starting age in chess *Developmental Psychology*, *43*.
- Gobet, F., de Voogt, A., & Retschitzki, J. (2004). *Moves in mind: The psychology of board games*. Hove, UK: Psychology Press.
- Gobet, F. & Simon, H. A. (1996a). Recall of rapidly presented random chess positions is a function of skill. *Psychonomic Bulletin & Review*, *3*, 159-163.
- Gobet, F. & Simon, H. A. (1996b). Templates in chess memory: A mechanism for recalling several boards. *Cognitive Psychology*, *31*, 1-40.
- Greenberg, D. L., & Rubin, D. C. (2003). The neuropsychology of autobiographical memory. *Cortex*, *39*, 687-728.
- Kopelman, M. D., & Kapur, N. (2001). The loss of episodic memories in retrograde amnesia: Single-case and group studies. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *356*, 1409-1421.
- Kopelman, M. D., Wilson, B., & Baddeley, A. D. (1990). *The autobiographical memory interview*. Bury St Edmunds: Thames Valley Test Company.
- Levine, B. (2004). Autobiographical memory and the self in time: Brain lesion effects, functional neuroanatomy, and lifespan development. *Brain and Cognition*, *55*, 54-68.
- Levine, B., Turner, G. R., Tisserand, D., Hevenor, S. J., Graham, S. J., & McIntosh, A. R. (2004). The functional neuroanatomy of episodic and semantic

- autobiographical remembering: A prospective functional MRI study. *Journal of Cognitive Neuroscience*, 16, 1633-1646.
- Maguire, E. A. (2001). Neuroimaging studies of autobiographical event memory. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 356, 1441-1451.
- Maguire, E. A. & Frith, C. D. (2003). Lateral asymmetry in the hippocampal response to the remoteness of autobiographical memories. *Journal of Neuroscience*, 23, 5302-5307.
- Maguire, E. A., Henson, R. N. A., Mummery, C. J., & Frith, C. D. (2001). Activity in prefrontal cortex, not hippocampus, varies parametrically with the increasing remoteness of memories. *Neuroreport*, 12, 441-444.
- Maguire, E. A., & Mummery, C. J. (1999). Differential modulation of a common memory retrieval network revealed by positron emission tomography, *Hippocampus*, 9, 54-61.
- Maguire, E. A., Mummery, C. J., & Buchel, C. (2000). Patterns of hippocampal-cortical interaction dissociate temporal lobe memory subsystems. *Hippocampus*, 10, 475-482.
- Markowitsch, H. J., Vandekerckhove, M. M. P., Lanfermann, H., & Russ, M. O. (2003). Engagement of lateral and medial prefrontal areas in the ecphory of sad and happy autobiographical memories. *Cortex*, 39, 643-665.
- Neisser, U. (1976). *Cognition and reality: Principles and implications of cognitive psychology*. New York, NJ: WH Freeman.
- Nichelli, P., Grafman, J., Pietrini, P., Alway, D., Carton, J. C., & Miletich, R. (1994). Brain activity in chess playing. *Nature*, 369, 191.

- Niki, K. & Luo, J. (2002). An fMRI study on the time-limited role of the medial temporal lobe in long-term topographical autobiographical memory. *Journal of Cognitive Neuroscience*, *14*, 500-507.
- Piefke, M., Weiss, P. H., Zilles, K, Markowitsch, H. J., & Fink, G. R. (2003). Differential remoteness and emotional tone modulate the neural correlates of autobiographical memory. *Brain*, *126*, 650-668.
- Tulving, E., Kapur, S., Craik, F. I. M., Moscovitch, M., & Houle, S. (1994). Hemispheric encoding/retrieval asymmetry in episodic memory: Positron emission tomography findings. *Proceedings of the National Academy of Sciences USA*, *91*, 2016-2020.
- Waters, A., Gobet, F., & Leyden, G. (2002). Visuo-spatial abilities in chess players. *British Journal of Psychology*, *30*, 303-311.

Table 1. Talairach coordinates of GM in all the contrasts of interest

Contrast	Vox.	Hem.	Brain region	BA	t-value	Z-value	Talairach		
							x	y	z
Own >	726	R	Middle occipital gyrus	18	6.25	6.07	30	-90	16
		R	Post cingulate/Parahippocampal g.	37/30	6.4	6.21	21	-49	8
Control		R	Parahippocampal gyrus	19	8.29	>7.8	27	-47	-5
	20	L	Superior parietal lobule	19	5.18	5.07	-21	-79	45
	22	R	Superior parietal lobule	7	5.04	4.95	24	-70	53
	529	L	Fusiform gyrus	37	7.13	6.86	-30	-53	-10
		L	Posterior cingulate	30	6.25	6.07	-24	-61	9
		L	Cerebellum		5.38	5.26	-42	-74	-16
	238	R	Precentral gyrus	4	6.11	5.94	50	9	11
		R	Inferior frontal gyrus	46	5.45	5.33	56	30	10
		R	Inferior frontal gyrus	47	4.67	4.59	50	47	-2
	627	L	Inferior frontal gyrus	45	6.96	6.71	-36	27	15
		L	Inferior frontal gyrus	45	6.77	6.54	-39	19	21
	21	R	Inferior frontal gyrus	47	4.86	4.77	30	29	-1
	27	L	Inferior frontal gyrus	11	4.67	4.59	-30	32	-9
	101	L	Medial frontal gyrus	6	5.88	5.73	-24	-7	42
45	R	Superior frontal gyrus	6	5.02	4.92	21	5	44	
Others >	1142	R	Middle occipital gyrus	18	6.03	5.86	33	-84	10
		R	Parahippocampal gyrus	19	8.19	7.79	27	-47	-5
Control		R	Cerebellum		6.3	6.12	45	-54	-23
	932	L	Middle occipital gyrus	18	8.05	7.68	-36	-90	5
		L	Fusiform gyrus	37	7.06	6.8	-30	-53	-10
		L	Fusiform gyrus	19	5.91	5.76	-42	-76	-14
	14	L	Superior parietal lobule	7	4.71	4.63	-21	-58	55
	20	L	Posterior cingulate	30	5.02	4.92	-24	-58	8
	20	L	Precentral gyrus	6	4.67	4.59	-24	-7	42
	8	R	Precentral gyrus	4	4.55	4.47	50	7	13
	7	L	Insula	13	4.62	4.55	-33	7	16
	6	R	Inferior frontal gyrus	47	4.4	4.34	33	29	-4
	41	R	Superior frontal gyrus	6	4.97	4.88	21	5	44
	Own >	37	L	Precuneus	31	3.63	3.59	-9	-48
Others	281	L	Superior temporal gyrus	22	3.77	3.73	-62	-52	16
		L	Superior temporal gyrus	39	3.76	3.72	-56	-57	25
		L	Inferior parietal lobule	40	3.73	3.68	-50	-50	44
	341	L	Inferior frontal gyrus	45	4.03	3.97	-56	27	10
		L	Middle frontal gyrus	8	3.82	3.77	-36	16	38
		L	Middle frontal gyrus	9	3.78	3.73	-45	33	29
	54	L	Superior frontal gyrus	9	4.05	4	-18	51	20
	25	L	Superior frontal gyrus	6	3.72	3.68	-12	15	60
33	L	Superior frontal gyrus	8	3.54	3.5	-6	37	45	

Note. In the first two contrasts a correction for multiple comparisons was performed, establishing the threshold at $p < 0.05$. In own > others no correction was carried out, and the threshold was established at $p < 0.001$. Talairach coordinates, Brodmann areas, t and z values, and number of voxels activated that belong to clusters of more than 5 voxels are displayed.

Table 2. Talairach coordinates of IM in all the contrasts of interest

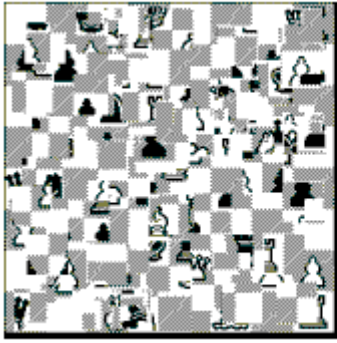
Contrast	Vox.	Hem.	Brain region	BA	t-value	Z-value	Talairach		
							x	y	z
Own > Control	1757	L	Middle occipital gyrus	19	10.37	>7.8	-30	-87	15
		L	Superior parietal lobule	7	9.37	>7.8	-24	-64	53
		L	Posterior cingulate	31	5.81	5.66	-15	-58	14
	1212	R	Middle occipital gyrus	19	9.48	>7.8	39	-78	12
		R	Superior parietal lobule	7	8.95	>7.8	27	-59	53
		R	Posterior cingulate	30	5.41	5.29	21	-54	22
	95	R	Inferior temporal gyrus	20	7.67	7.35	53	-53	-12
	416	L	Parahippocampal gyrus	35	7.2	6.92	-24	-39	-13
	66	L	Inferior temporal gyrus	37	6.15	5.97	-59	-53	-7
	121	R	Parahippocampal gyrus	35	5.86	5.71	27	-38	-3
		R	Fusiform gyrus	37	4.77	4.69	33	-42	-18
	834	L	Inferior frontal gyrus	44	9.04	>7.8	-42	7	27
		L	Inferior frontal gyrus	46	5.7	5.55	-48	41	6
		L	Inferior frontal gyrus	47	4.56	4.49	-39	40	-15
	470	R	Inferior frontal gyrus	44	8.32	>7.8	39	16	21
	124	L	Middle frontal gyrus	6	6.11	5.94	-21	2	50
		L	Middle frontal gyrus	6	5.98	5.82	-24	12	60
	30	R	Orbitofrontal gyrus	11	5.88	5.72	30	37	-20
	13	L	Cerebellum		4.74	4.66	-21	-46	-41
Others > Control	901	L	Middle occipital gyrus	18	8.93	>7.8	-30	-87	13
		L	Superior parietal lobule	7	7.66	7.34	-24	-67	53
	836	R	Middle occipital gyrus	19	7.51	7.2	39	-78	9
		R	Superior parietal lobule	7	7	6.74	27	-56	53
		R	Superior parietal lobule	7	5.94	5.78	33	-72	26
	39	R	Inferior temporal gyrus	20	5.95	5.79	53	-56	-12
	158	L	Fusiform gyrus	36	5.62	5.48	-27	-36	-16
	55	R	Parahippocampal gyrus	36	4.97	4.87	33	-33	-14
	164	R	Inferior frontal gyrus	45	6.36	6.17	39	19	21
	128	L	Inferior frontal gyrus	44	5.77	5.62	-48	7	25
Own > Others	518	L	Inferior parietal lobule	40	5	4.9	-42	-45	41
		L	Superior parietal lobule	7	3.96	3.91	-36	-43	63
	626	L	Superior frontal gyrus	6	4.72	4.64	-21	14	49
		L	Middle frontal gyrus	46	4.19	4.13	-42	39	15
		L	Middle frontal gyrus	6	4	3.95	-27	10	33
	61	L	Medial frontal gyrus	10	3.91	3.86	-18	58	-3
		L	Middle frontal gyrus	10	3.73	3.69	-30	55	-10
		L	Middle frontal gyrus	10	3.34	3.31	-39	43	-12
	24	R	Middle frontal gyrus	6	3.76	3.72	42	11	55
8	L	Cerebellum		3.39	3.36	-6	-48	-28	

Note. In the first two contrasts a correction for multiple comparisons was performed, establishing the threshold at $p < 0.05$. In own > others no correction was carried out and the threshold was established at $p < 0.001$. Talairach coordinates, Brodmann areas, t and z values, and number of voxels activated of clusters of more than 5 voxels are displayed.

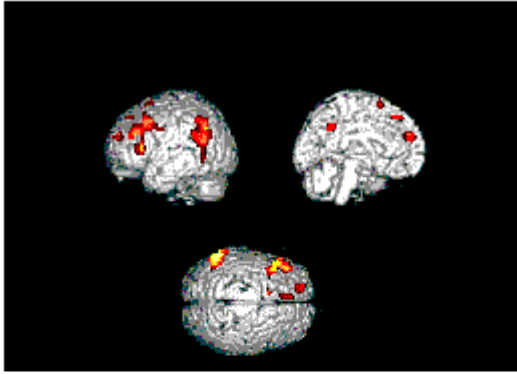
Figure captions

Figure 1. Stimuli used in the experiment. The first is the control stimulus. The second is an example of stimuli generated from games of the participants or other players' games. Both "own" (OW) and "others" (OT) positions have the same features, i.e., chess positions that belong to a real game. The only difference between them is the fact that one belongs to the participants' own games and the other does not.

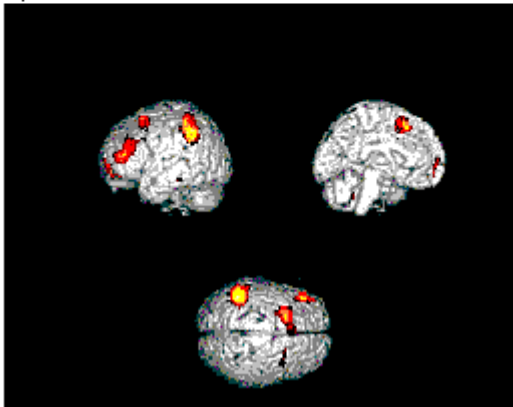
Figure 2. Contrast own > others. Brain areas activated are displayed in a brain template: a) GM, b) IM. The top left image is a left lateral view of the brain, the top right image is a left medial view of the brain, and the bottom image is an upper view of the brain.



A)



B)



Footnote

¹ Elo (1978) developed the rating scale that is now used by the World Chess Federation (FIDE). The scale has a normal distribution and a standard deviation of 200 points. The best player of the world has around 2800 points and the weakest 1200. FIDE awards players with titles for their performances in specific tournaments. As an approximation, players above 2300, 2400 and 2500 receive the titles of FIDE masters, international masters, and international grandmasters, respectively.