Journal of Experimental Social Psychology 46 (2010) 229–232

Contents lists available at ScienceDirect

Journal of Experimental Social Psychology

journal homepage: www.elsevier.com/locate/jesp

FlashReport

Your mistakes are mine: Self-other overlap predicts neural response to observed errors

Sonia K. Kang *, Jacob B. Hirsh, Alison L. Chasteen

Department of Psychology, University of Toronto, Canada

ARTICLE INFO

Article history:
Received 16 July 2009
Revised 25 August 2009
Available online 23 September 2009

Keywords:
Self-other overlap
Electrophysiology

ABSTRACT

This study examined whether the degree to which one perceives overlap between the self and another person predicts the magnitude of the neural response of the anterior cingulate cortex (ACC) following the observation of that person's errors. Specifically, we measured the magnitude of the observational feedback-related negativity (oFRN), an event-related potential associated with observing someone else make an error, while participants watched strangers or friends complete a Stroop task. Results show stronger activation of the ACC, as indexed by the oFRN, for those who observed friends compared to those who observed strangers. This effect was mediated by the degree to which participants included the other in their conception of the self. This study contributes a unique examination of real-life close pairs to a growing body of research showing that social factors can greatly impact neural processing.

Introduction

Underlying much of human survival is the ability to learn from one's mistakes. Critical to this ability is the basic recognition that one has made a mistake in the first place, an important responsibility of the brain's confliction-detection and performance-monitoring systems. A number of studies have provided converging evidence that the anterior cingulate cortex (ACC) is involved in these processes (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Carter et al., 1998; Holroyd & Coles, 2002; MacDonald, Cohen, Stenger, & Carter, 2000; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). When conflict between an intended and actual response is detected, ACC activity improves behavioral regulation via engagement of the cognitive control mechanisms of the prefrontal cortex (PFC; Botvinick et al., 2001; Gehring & Knight, 2000; Kerns et al., 2004; Luu, Tucker, Derryberry, Reed, & Poulsen, 2003). Research employing the event-related potential (ERP) technique has identified a number of indicators of ACC activity. One of these, the feedback-related negativity (FRN), is elicited by negative feedback stimuli, and manifests as a negative deflection of the ERP peaking between 200 ms and 350 ms after the presentation of feedback (e.g., Hajcak, Moser, Holroyd, & Simons, 2006; Miltner, Braun, & Coles, 1997). The FRN is not only elicited after one's own mistakes; an observational FRN (oFRN) is also elicited after observing someone else make an error (e.g., Yu & Zhou, 2006), suggesting that the neural processes associated with learning by observation are similar to those associated with learning by doing. In this study, we examined whether perceived overlap between the self and another person predicts the magnitude of the neural response following the observation of another's errors.

A growing body of research provides converging evidence that the neural mechanisms involved in monitoring one's own actions are similar to those involved in monitoring others' actions (e.g., Miltner, Brauer, Hecht, Trippe, & Coles, 2004; Rizzolatti, Fogassi, & Gallese, 2001; Shane, Stevens, Harenski, & Kiehl, 2008; van Schie, Mars, Coles, & Bekkering, 2004). Recently, researchers have begun to examine the influence of social factors on this "mirror" performance-monitoring system. For example, mirroring is stronger when we observe racial in-group compared to out-group members (Xu, Zuo, Wang, & Han, 2009), and when we observe similar compared to dissimilar others (Mitchell, Macrae, & Banaji, 2006), and some have suggested that gender moderates the reactivity of the neural mirroring system, with women showing more vicarious activation than men (Fukushima & Hiraki, 2006). In addition, research suggests that neural mirroring should be strongest when observing those with whom we feel closest (e.g., Singer et al., 2004). Specifically, vicarious activation appears to be influenced by self-relevance (Itagaki & Katayama, 2008), empathy (Fukushima & Hiraki, 2009; Shane, Stevens, Harenski, & Kiehl, 2009), perspective-taking (Shane et al., 2009), self-identification (Newman-Norlund, Ganesh, van Schie, De Bruijn, & Bekkering, 2009), and perceived similarity (Carp, Halenar, Quandt, Sklar, & Compton, 2009).

Particularly important to the current study is previous work linking vicarious activation of the performance-monitoring system to empathy, self-identification, and perceived similarity. In a func-

* Corresponding author. Address: Department of Psychology, University of Toronto, 100 St. George St., Toronto, Ontario, Canada M5S 3G3. Fax: +1 416 978 4811.

E-mail address: sonia.kang@utoronto.ca (S.K. Kang).

0022-1031/$ - see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.jesp.2009.09.012

tional magnetic resonance imaging (fMRI) study, Shane et al., (2009) showed that self-reported general empathic concern was positively correlated with hemodynamic responding in the ACC when watching a video of an actor performing a Go-NoGo task. Increased hemodynamic responding was also shown when watching videos of soccer players from teams with which a participant identified compared to those with which participants did not identify (Newman-Norlund et al., 2009). Finally, Carp and his colleagues (2009) had participants observe a confederate complete a speeded response task, and found a positive correlation between the magnitude of two ERPs (the observational ERN and observational error-related positivity) and self-reported perceived similarity with the confederate. Related to these studies, we examined vicarious activation of the neural performance-monitoring system while participants watched strangers or close others complete the color-naming Stroop task (Stroop, 1935). Although testing a similar question, our study is unique from these previous studies in a number of ways. For example, we compared neural activity while watching strangers versus actual close others in vivo, not just confederates, and not just while watching videos. Second, we measured self-other overlap with the actual individual being observed, not just general empathy or perceived similarity with a confederate.

Self-other overlap or inclusion of other in the self (Aron, Aron, & Smollan, 1992; Aron, Aron, Tudor, & Nelson, 1991) has become an important construct in the study of close relationships. The notion of closeness as including the other in the self (Aron & Aron, 1986; Aron et al., 1991) stems from the idea that close relationships can be identified as those in which an individual acts as though some or all aspects of the partner are partially the individual's own. A greater sense of self-other overlap can lead to more empathic responding (Cialdini, Brown, Lewis, Luce, & Neuberg, 1997), improve perspective-taking ability (Aron et al., 1991), foster social bonds (Galinsky, Ku, & Wang, 2005), and motivate a more complex understanding of others (Waugh & Fredrickson, 2006). Although by no means a comprehensive review, these findings converge on the idea that including the other in the self facilitates social processing and behavior in a number of ways. We hypothesized that inclusion of the other in the self would also lead to increased vicarious activation of the neural performance-monitoring and conflict-detection systems. Specifically, we predicted that the more that one included another in their conceptualization of the self, the greater would be the magnitude of the oFRN following the other's errors. In essence, when we include another in the self, their mistakes become our own mistakes.

In order to test our hypothesis, we invited same-sex pairs of strangers and pairs of close friends to the laboratory. We recorded brain activity using EEG while participants watched their partner complete the Stroop task. The relationship between this brain activity and self-reported inclusion of the other in the self was examined.

Method

Participants

Participants were 24 right-handed introductory psychology students (M_{age} = 18.96 years, SD = 1.99 years) at the University of Toronto (13 female, 11 male) who participated for course credit. Individuals in the close-pairs group had known each other for between 1 and 27 years (M = 8.00, SD = 8.50). Individuals in the strangers group had not had any prior contact.

Materials

Inclusion of other in the self scale (IOS; Aron et al., 1992)

The IOS is a single-item, pictorial measure of closeness. Participants choose the picture which best describes their relationship with another person from a series of seven Venn-like diagrams depicting various degrees of overlap between circles labelled "Self" and "Other". The scale is scored from 1 (no overlap) to 7 (almost complete overlap).

Color-naming Stroop task

In the Stroop task (Stroop, 1935), color words are presented in colors that either match or conflict with the semantic meaning of the words. Participants are instructed to press one of four colored buttons that correspond to the font color of the stimulus word (red, green, blue, or yellow). Each word appeared for a random duration between 250 ms and 350 ms, with a maximum response window of 800 ms. A random inter-trial interval between 800 ms and 1200 ms was used. Performance feedback lasting 500 ms was provided at the end of each trial between 250 ms and 350 ms after the response was made, just prior to the inter-trial interval. This feedback indicated whether or not a correct response was made. Random durations and timings were employed to reduce the EEG artifacts that can arise when timings are held constant (Luck, 2005). A practice session preceded 15 blocks of 12 trials each (8 congruent, 4 incongruent), with short breaks between blocks.

Procedure

Participants were invited to the laboratory to participate in a study examining brain activity while watching another person complete a cognitive task. Participants were randomly assigned to one of two conditions: Strangers or Friends. In the Strangers condition, participants were randomly paired. In the friends condition, participants brought a close relationship partner (e.g., friend, sibling, parent) with them to the lab. After completing an informed consent form, the observer was hooked up to the electroencephalogram (EEG) while the performer was seated in front of a nearby computer to complete the color-naming Stroop task. Observers were asked to watch carefully as their partner completed the Stroop task. Observers and performers sat side-by-side, and both partners were instructed to watch the computer screen and minimize eye movement during the trials.

In order to ensure that observers attended to the performance feedback, they counted the number of errors and correct trials for each block of trials. Additional motivation was provided by informing participants that the most accurate observer and the most accurate performer within the study would receive a monetary bonus.

EEG activity was recorded from the observer as the performer completed the Stroop task. Following each block, the observer recorded the number of error and correct trials for that block. At the end of the Stroop task, both participants completed a demographics questionnaire and the IOS.

Electrophysiological processing

EEG was recorded from 32 Ag/AgCl sintered electrodes in a stretch-lycra cap. Vertical eye movements (VEOG) were monitored via a supra- to sub-orbital bipolar montage. EEG and VEOG recordings were digitized at 560 Hz using ASA acquisition hardware (Advanced Neuro Technology B.V., Enschede, Netherlands) with average-ear references and a forehead ground. Electrode impedances were kept below 5 kOhm for all recordings. EEG was corrected for VEOG (eye movement) artifacts using the SOBI procedure (Tang, Liu, & Sutherland, 2005). Frequencies below 1 Hz and above 15 Hz were digitally filtered (96 dB, zero-phase shift). The signal was baseline corrected by subtracting the average voltage occurring in the 100 ms pre-response. Movement artifacts were detected with a −75 μV and +75 μV threshold. Correct and incorrect feedback trials were averaged separately with an epoch from 100 ms pre-response to 500 ms post-response. FRNs were quantified as the peak minimum deflection between 200 and 350 ms post-feedback at the central midline electrode (Cz). As in previous research with the FRN, stimulus-locked ERP activity was recorded in relation to the receipt of the feedback stimulus.

Results

We first examined whether or not the observer FRN was displayed in both groups. Paired-sample *t*-tests were used to compare the FRN on incorrect and correct feedback trials. Incorrect feedback did indeed produce a larger negative ERP deflection compared to correct feedback for both Strangers, $t(11) = 3.15$, $p < .01$, and Friends, $t(11) = 4.58$, $p < .01$. We next used the FRN difference wave (computed as the FRN on correct trials minus the FRN on incorrect trials) to examine differences in the magnitude of the response across the groups. Results confirmed our hypothesis that individuals would demonstrate a larger electrophysiological response when observing a friend performing the task, compared to watching a stranger, $t(22) = -1.83$, $p < .05$.

We next examined the relationship between the oFRN and responses on the IOS scale, which differed significantly for participants in the friends group ($M = 5.92$, $SD = 0.79$) and the Strangers group ($M = 2.25$, $SD = 1.55$), $t(22) = 7.32$, $p < .01$. A significant correlation was found: compared to those who reported less self-other overlap, participants who felt closer to the performer displayed a larger (more negative) FRN when that person received negative feedback ($r = -.46$, $p < .05$). A bootstrapped correlation analysis with 10,000 repetitions confirmed that this effect was not driven by a subset of outliers, as the 90% confidence intervals ranged from −0.13 to −0.68 ($SE = 0.17$). The correlation remained similar when calculating the FRN as the mean voltage between 200 and 350 ms post-feedback, rather than as the peak minimum deflection ($r = -.46$, $p < .05$), as well as when using a peak-to-peak measure of FRN amplitude ($r = -.35$, $p < .05$). A mediation analysis using the product of coefficients method recommended by MacKinnon, Lockwood, Hoffman, West, and Sheet (2002) confirmed that the relationship between experimental group membership (Strangers vs. Friends) and the magnitude of the observer FRN was mediated by the degree of self-other overlap as measured by the IOS scale ($z' = 1.40$, $p < .01$). Note that we are not suggesting that group membership directly caused varying degrees of self-other closeness, simply that the predictive variance of group membership was also reflected in the IOS scores. In fact, self-other overlap appears to have been the better predictor of observer FRN magnitude, as it still demonstrated a substantive correlation when controlling for experimental group membership (partial $r = -.30$). Presumably, this is because the IOS scale provides more detailed information about relationship closeness than does the broad distinction of Friend vs. Stranger. All results remained stable when statistically controlling for age, gender, and familiarity with the English language. Fig. 1 presents the ERP graphs, while Fig. 2 presents the topography of the FRN. While it appears that individuals in the friends condition had a larger negative deflection 100 ms post-feedback, the amplitude difference between groups was not significant, $p > .25$.

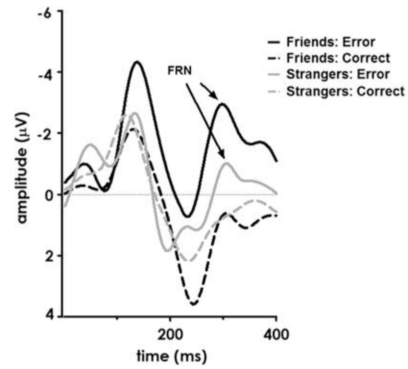

Fig. 1. Event-related potentials at Cz on observed correct and error trials for individuals in the Friends and Strangers groups.

An analysis of observer counting errors found no difference between those who observed friends ($M = 0.83$, $SD = 1.3$) and those who observed strangers ($M = 1.5$, $SD = 1.6$), $t(22) = -1.12$, $p > .05$, suggesting that the observed effects were not simply due to attentional differences between group members. Finally, error rates on the Stroop task did not differ between the two groups (Friends: $M = 0.09$, $SD = 0.04$; Strangers: $M = 0.08$, $SD = 0.04$; $t(22) = .59$, $p > .05$).

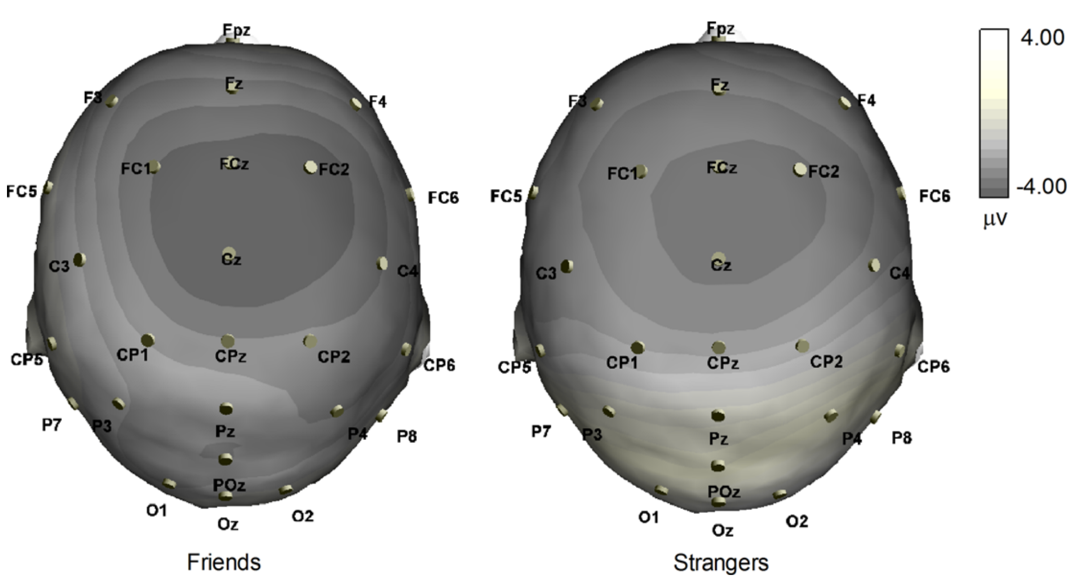

Fig. 2. Spatial distribution of the feedback-related negativity for individuals in the Friends and Strangers groups. Headmaps reflect the difference between error trials and correct trials.

Discussion

In this study, we tested the relationship between self-other overlap and vicarious activation of the neural performance-monitoring system, as revealed by variation in the oFRN following the observation of another person's errors on a cognitive task. As predicted, we found that the more that one included another in his or her conception of the self, the greater the neural response when watching that partner make errors on a Stroop task. Our study adds to a growing body of literature showing that social factors can have a large impact on neural responding.

An interesting possibility raised by the current results is that observational learning may be more effective when the vicarious learner has greater self-other overlap with the performer. The FRN is thought to play an important role in feedback learning, as it partially reflects the motivational relevance of negative feedback information (Holroyd & Coles, 2002; Sailer, Fischmeister, & Bauer, 2008). Given that individuals display a larger FRN when observing mistakes made by friends compared to strangers, they may also be undergoing more effective vicarious learning with close others. A limitation of the current study is that we did not employ a paradigm in which real evidence of learning and improvement could be observed over the experimental session. Future research should test whether observational learning is indeed more effective with close-paired individuals, as suggested by the current EEG results. These results would provide even more insight into the important relationship between self-other overlap and vicarious activation of the performance-monitoring system.

Acknowledgment

This study was supported by grants from the Social Sciences and Humanities Research Council of Canada awarded to all three authors. Data were collected at the Centre for Biological Timing and Cognition and Department of Psychology, University of Toronto.

References

Aron, A., & Aron, E. N. (1986). *Love as the expansion of self: Understanding attraction and satisfaction*. New York: Hemisphere.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of other in the self scale and the structure of interpersonal closeness. *Journal of Personality and Social Psychology, 63*, 596–612.

Aron, A., Aron, E. N., Tudor, M., & Nelson, G. (1991). Close relationships as including other in the self. *Journal of Personality and Social Psychology, 60*, 241–253.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and conflict control. *Psychological Review, 108*, 624–652.

Carp, J., Halenar, M. J., Quandt, L. C., Sklar, A., & Compton, R. J. (2009). Perceived similarity and neural mirroring: Evidence from vicarious error processing. *Social Neuroscience, 4*, 85–96.

Carter, C. S., Braver, T. S., Barch, D. M., Botvinick, M., Noll, D., & Cohen, J. D. (1998). Anterior cingulate cortex, error detection, and the on line monitoring of performance. *Science, 280*, 747–749.

Cialdini, R. B., Brown, S. L., Lewis, B. P., Luce, C., & Neuberg, S. L. (1997). Reinterpreting the empathy–altruism relationship: When one into one equals oneness. *Journal of Personality and Social Psychology, 73*, 481–494.

Fukushima, H., & Hiraki, K. (2006). Perceiving an opponent's loss: Gender-related differences in the medial–frontal negativity. *Social Cognitive and Affective Neuroscience, 1*, 149–157.

Fukushima, H., & Hiraki, K. (2009). Whose loss is it? Human electrophysiological correlates of non-self reward processing. *Social Neuroscience, 4*, 261–275.

Galinsky, A. D., Ku, G., & Wang, C. S. (2005). Perspective-taking and self-other overlap: Fostering social bonds and facilitating social coordination. *Group Processes and Intergroup Relations, 8*, 109–124.

Gehring, W. J., & Knight, R. T. (2000). Prefrontal-cingulate interactions in action monitoring. *Nature Neuroscience, 3*, 516–520.

Hajcak, G., Moser, J. S., Holroyd, C. B., & Simons, R. F. (2006). The feedback-related negativity reflects the binary evaluation of good versus bad outcomes. *Biological Psychology, 71*, 148–154.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review, 109*, 679–709.

Itagaki, S., & Katayama, J. (2008). Self-relevant criteria determine the evaluation of outcomes induced by others. *Cognitive Neuroscience and Neuropsychology, 19*, 383–387.

Kerns, J. G., Cohen, J. D., MacDonald, A. W., Cho, R. Y., Stenger, V. A., & Carter, C. S. (2004). Anterior cingulate conflict monitoring and adjustments in control. *Science, 303*, 1023–1026.

Luck, S. J. (2005). *The event related potential technique*. Cambridge, MA: MIT Press.

Luu, P., Tucker, D. M., Derryberry, D., Reed, M., & Poulsen, C. (2003). Electrophysiological responses to errors and feedback in the process of action regulation. *Psychological Science, 14*, 47–53.

MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. S. (2000). Dissociating the role of dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science, 288*, 1835–1838.

MacKinnon, D., Lockwood, C., Hoffman, J., West, S., & Sheets, V. (2002). A comparison of methods to test mediation and other intervening variable effects. *Psychological Methods, 7*(1), 83–104.

Miltner, W. H. R., Brauer, J., Hecht, H., Trippe, R., & Coles, M. G. H. (2004). Parallel brain activity for self-generated and observed errors. In M. Falkenstein (Ed.), *Error, conflict and the brain* (pp. 124–128). Leipzig: MPI of Cognitive Neuroscience.

Miltner, W. H. R., Braun, C. H., & Coles, M. G. H. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: Evidence for a "generic" neural system for error detection. *Journal of Cognitive Neuroscience, 9*, 788–798.

Mitchell, J. P., Macrae, C. N., & Banaji, M. R. (2006). Dissociable medial prefrontal contributions to judgments of similar and dissimilar others. *Neuron, 50*, 655–663.

Newman-Norlund, R. D., Ganesh, S., van Schie, H. T., De Bruijn, E. R. A., & Bekkering, H. (2009). Self-identification and empathy modulate error-related brain activity during the observation of penalty shots between friend and foe. *Social Cognitive and Affective Neuroscience, 4*, 10–22.

Ridderinkhof, K. R., Ullsperger, M., Crone, E. A., & Nieuwenhuis, S. (2004). The role of the medial frontal cortex in cognitive control. *Science, 306*, 443–447.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience, 2*, 661–670.

Sailer, U., Fischmeister, F. Ph. S., & Bauer, H. (2008). Changes in the feedback-related negativity with learning. *International Journal of Psychophysiology, 69*, 217.

Shane, M. S., Stevens, M. C., Harenski, C. L., & Kiehl, K. (2008). Neural correlates of the processing of another's mistakes: Underpinning for social and observational learning. *Neuroimage, 42*, 450–459.

Shane, M. S., Stevens, M. C., Harenski, C. L., & Kiehl, K. (2009). Double dissociations between perspective-taking and empathic-concern as predictors of hemodynamic response to another's mistakes. *Social Cognitive and Affective Neuroscience, 4*, 111–118.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R. J., & Frith, C. D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303*, 1157–1162.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643–662.

Tang, A., Liu, J., & Sutherland, M. (2005). Recovery of correlated neuronal sources from EEG: The good and bad ways of using SOBI. *Neuroimage, 28*, 507–519.

van Schie, H. T., Mars, R. B., Coles, M. G., & Bekkering, H. (2004). Modulation of activity in medial frontal and motor cortices during error observation. *Nature Neuroscience, 7*, 549–554.

Waugh, C. E., & Fredrickson, B. L. (2006). Nice to know you: Positive emotions, self-other overlap, and complex understanding in the formation of a new relationship. *The Journal of Positive Psychology, 1*, 93–106.

Xu, X., Zuo, X., Wang, X., & Han, S. (2009). Do you feel my pain? Racial group membership modulates empathic neural responses. *Journal of Neuroscience, 29*, 8525–8529.

Yu, R., & Zhou, X. (2006). Brain responses to outcomes of one's own and other's performance in a gambling task. *Cognitive Neuroscience and Neuropsychology, 17*, 1747–1751.