Out of the group, out of control? The brain responds to social exclusion with changes in cognitive control

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The effects of social exclusion are far-reaching, both on an emotional and behavioral level. The present study investigates whether social exclusion also directly influences basic cognitive functions, specifically the ability to exert cognitive control. Participants were either excluded or included while playing an online game. To test whether exclusion altered cognitive control, we measured the electrophysiological responses to a Go/No Go task. In this task participants had to withhold a response (No Go) on a small number of trials while the predominant tendency was to make an overt (Go) response. Compared to Go trials the event-related potential evoked by No Go trials elicited an increased N2, reflecting the detection of the response conflict, followed by an increased P3, reflecting the inhibition of the predominant response. The N2 effect was larger for participants who had experienced exclusion, while the P3 effect was smaller. This indicates that exclusion leads to an increased ability to detect response conflicts, while at the same time exclusion decreases the neural processes that underlie the inhibition of unwanted behavior.

Keywords: social exclusion; ostracism; N2; P3; EEG; ERP

Humans and other primates have evolved to function in groups, and thus experience a strong need to feel close and connected to others. As a result, being excluded from a social structure has vast consequences for the ostracized. Indeed, everyone can remember, or at the very least imagine, what it is like to be selected last for a team or to be declined an invitation to a party where everyone else is invited. When recalling such events, what probably stands out most are the emotional consequences of exclusion, such as anger, anxiety, depression or shame (Baumeister and Leary, 1995; Eisenberger et al., 2003). Even though the emotional consequences are apparent, the effects of exclusion are not limited to the domain of feelings. Exclusion fosters aggression: when given the opportunity, excluded people will dictate that innocent targets are subjected to eating larger amounts of hot sauce (Warburton et al., 2006) or longer and more intense bursts of noise (Twenge et al., 2001). Excluded people also show evidence for an increase in impulsive behavior, such as less self-regulation (Baumeister et al., 2005; DeWall et al., 2007) and more risky behavior (Twenge et al., 2002). At the same time social exclusion seems detrimental to overall cognitive functioning (Baumeister et al., 2002).

It seems logical to assume that these behavioral consequences of exclusion are linked to exclusion-related emotions. This does not seem to be the case: the changes in behavior are not mediated by the emotions evoked by exclusion (Twenge et al., 2001; Baumeister et al., 2002; Twenge et al., 2002; Buckley et al., 2004). Since emotional turmoil is not the main factor that underlies the pattern of behavior observed after social rejection we must further investigate other candidates. Here, we investigate one such candidate, namely the cognitive control system. Cognitive control, or the executive function system, is the collection of cognitive functions that allows people to deal with novel situations, to correct errors and override automatic responses for more contextually appropriate behavior. Cognitive control is a broad construct that involves a wide range of psychological functions such as working memory, attention and conflict detection, as well as the initiation, execution, monitoring and inhibiting of actions.

It is important to note that the concept of cognitive control is different from the concept of sense of control as it is framed in the need-threat model of exclusion (Williams, 2009). Within this model, Williams describes that excluded people almost without exception experience a loss of control over their environment and actions of others. Such an explicit experience of loss of control conceptually differs from the (largely implicit) cognitive functions that deal with cognitive control. Yet the effects exclusion on functional cognitive control could directly or indirectly contribute to feelings of control over one’s environment.

Experiments studying cognitive control have shown a link between impulsive behavior such as aggression and risk-taking and a decrease in cognitive control (Posner and Rothbart, 2000; Horn et al., 2003; Wilkowski et al., 2010). In addition, the ability to exert cognitive control is also involved in higher cognitive functions such as reasoning (Greene et al., 2004). The pattern of behavior linked to exclusion (i.e. increased impulsivity combined with less intelligent thought) could thus be based on an underlying decrease of the mental processes involved in cognitive control.

A direct indication that exclusion limits cognitive control is the finding that social exclusion is related to a decrease in self-regulation. For example, excluded people ate more than included controls when they were offered unhealthy but delicious food, indicating that they were less able to control their behavior (Baumeister et al., 2005; Oaten et al., 2008). Changes in such self-regulatory behavior have been linked to changes in basic mental processes involved in cognitive control (Hofmann et al., 2012). Indeed, a study by Campbell and colleagues (2006) suggests that changes in cognitive control underlie the link between exclusion and decreased self-regulation: brain imaging of people solving math problems after they were told that they would lead lonely lives showed decreased activity in brain regions associated with cognitive control (Campbell et al., 2006). This indicates that the idea of being excluded at some point in the future is related to a decrease in activity in areas that underlie control when performing a difficult task.

Although the current body of literature suggests that exclusion leads to a decrease in cognitive control, there is little direct evidence that the observed effects of exclusion on feelings of control, self-regulation and aggression are due to changes in the cognitive control system. One notable exception is a study by Jamieson and colleagues (Jamieson...
et al., 2010) who used an antisaccade task to measure cognitive inhibition in excluded and included participants. In an antisaccade task, people have to move their eyes in the opposite direction from a sudden onset stimulus. However, the reflexive, prepotent response is to move the eyes towards the onset. The proportion of erroneous eye movements towards the onset is thus an indicator of (un)successful inhibition (Munoz and Everling, 2004; Nieuwenhuis et al., 2004). Jamieson and colleagues (2010) found that excluded participants made more reflexive eye movements towards the onset, which indicates that exclusion makes it harder to inhibit prepotent responses.

In the present experiment, we use electrophysiological measures to test whether exclusion directly alters the mental processes that underlie cognitive control. We explored whether the experience of social exclusion leads to a decrease in the neural processes that underlie our ability to control behavior, specifically the ability to detect response conflicts, and to inhibit unwanted but prepotent responses.

Participants played a virtual ball-tossing game, in which they were either excluded, or allowed to play along. To measure differences in the level of cognitive control between excluded and included participants, we recorded the electro-encephalogram (EEG) during a Go/No Go task. In this Go/No Go task, which is designed to directly tap into cognitive control processes, participants had to withhold a response (No Go) while the predominant tendency was to make an overt (Go) response. For each type of trials, the specific brain activation related to that trial (ERP) showed which mental processes were more, or less, active when processing the stimuli and preparing and completing a response.

High-conflict No Go trials, for which a high level of behavioral inhibition is needed, usually evoke a larger negative potential with a maximum amplitude around 200 ms, the P3 (Pfefferbaum et al., 1985; Jodo and Kayama, 1992; van Boxtel et al., 2001; Bekker et al., 2004) compared to Go trials. These event-related components reflect different processes that underlie the ability to regulate behavior. The N2 is thought to represent the detection of the response conflict (Nieuwenhuis et al., 2003; Donkers and Van Boxtel, 2004), while the P3 represents inhibitory processes (Ramaurt et al., 2004; Smith et al., 2007). The relative increase of the N2 and P3 component in No Go compared to Go trials (to which we shall refer as the N2 effect and P3 effect from now on) thus reflect the different cognitive building blocks that together form the ability to exert cognitive control over behavior. This allows us to directly explore not only whether social exclusion influences the mental fundaments of cognitive control, but also on which specific levels.

We expect that both excluded and included participants detect the response conflict posed by No Go trials, and attempt to inhibit the unwanted inclination to press the button in response to a No Go stimulus. Therefore, we expect both excluded and included participants to show an N2 (reflecting conflict detection) and P3 (reflecting behavioral inhibition) effect for No Go compared to Go trials. The relative differences between the amplitude of the N2 and P3 effect for excluded and included participants will reveal how exclusion affects the ability to regulate behavior. If exclusion alters the ability to detect conflicts, we expect to see a difference in the N2 effect for excluded participants compared to included participants: A relative decrease indicates less detected conflict, while a relative increase indicates more detected conflict. Along the same lines, if exclusion influences the ability to inhibit responses, we expect to see a difference in the P3 effect, with a larger P3 effect for excluded subjects indicating that they devote more effort to inhibiting their responses, while a smaller P3 effect indicates less inhibition.

**METHODS**

**Participants**

Thirty-four students from the university of Amsterdam participated for research credit or payment of €14. Two participants were excluded from the analysis because of equipment failure. Of the remaining 32 participants 22 were female, and their age ranged from 18 to 35 years with a mean of 21.8 years. All participants had corrected to normal vision, were right-handed, neurologically healthy and did not take any medication that might influence the EEG.

**Materials**

**Cyberball game**

To induce the experience of exclusion, participants played a modified version of the Cyberball paradigm designed by Williams and Jarvis (2006). In this game, participants played a ball-tossing game with two other players, who were represented on-screen by animated icons. Participants were led to believe that they were playing against other players on the internet, although the other players were in fact simulated by the computer. At the beginning of the game, participants were shown a screen stating ‘waiting for other participants to log in’. After a minute, the login screen disappeared and the ball-tossing game started. In the inclusion condition, the participants played a practice round in which they received the ball from the two other players from time to time, and then had to decide to which player to pass the ball. After the practice blocks the participant was told that there was now an opportunity for the gamers to chat, and that two of the three gamers would be selected at random to talk. The computer then ‘selected’ the other players to chat, and the participant saw a chat-session between the other players (with preprogrammed responses), in which the participant was called incompetent. The game continued after the chat-session, but the other two players only passed the ball to each other, excluding the participant. In the inclusion condition, there was no insulting chat-session, and the other two players occasionally passed the ball to the participant until the end of the game.

**Go/No Go task**

Participants were instructed to react to targets with a key press (‘Go’ trials), and to not make any response to a non-target (‘No Go’ trials). Because Go trials in the Go/No Go task are more frequent than No Go trials, not reacting to a No Go trial requires monitoring and inhibiting a prepared motor response. In this experiment, participants were asked to react to a central letter, sided by three flankers on each side. If the central letter was an ‘T’ (Go trials; presented stimulus: SSSTSSS), participants had to press the space bar. If the central letter was an ‘H’ (No Go trial; presented stimulus: SSSHSSS), participants had to withhold their response. Before each trial, a fixation cross was shown for an average of 500 ms (randomly varied between 400 and 600 ms), after which the Go or No Go stimulus was shown for 200 ms. The critical stimulus was followed by a 50 ms mask (XXXXXXXX), and a response screen which disappeared as the participant made a response, or after 1 second if no response was given. If the participant failed to respond to a Go trial or erroneously responded to a NoGo trial, an ‘error’ screen appeared for 400 ms. This screen showed the Dutch word for ‘error’ (‘fout’) in red. Participants completed 500 trials in total. Of these trials, 350 were Go trials (70%) and 150 were No Go trials (30%). Go and No Go trials were randomly intermixed.

**Procedure and EEG recording**

After reading and signing a consent form participants were fitted with the EEG-cap with 32 + 2 electrodes (Fp1, Fp2, AF3, AF4, F7, F3, Fz, F4,
F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, PO3, PO4, O1, Oz and O2; CMS and DRL). Blinks and eye-movements were registered by placing two electrodes under and next to the left eye. Two additional electrodes were placed on the left and right mastoid to allow for offline rereferencing of the EEG signal. EEG was recorded with a Biosemi active-electrode system (Biosemi Inc., Amsterdam, The Netherlands). The signal was amplified by a BioSemi ActiveTwo amplifier (−3 dB at ~102 Hz low-pass, fully DC coupled) with a sample rate of 512 Hz.

Participants were instructed that the experiment consisted of two independent parts, an online game intended to study mental imagery, and a reaction time task to study behavioral control. The experimental session started with the Cyberball game. Participants were randomly assigned to the exclusion or the inclusion condition. Participants were instructed, since the goal of this game was to study mental imagery in an interactive virtual environment, to really mentally envision playing the game with the other players.

After participants finished the Cyberball game, they were told that they would now do an unrelated second experiment in which their control would be tested. Participants were instructed to avoid blinks and eye-movement when the trials were presented on screen. Instead they were encouraged to blink on designated intervals, during a 2-s 'blink break' which appeared every fifth trial. This screen showed the Dutch word for ‘blink’ ('knipperen').

Data analysis

Behavioral data
The response time data to correct responses were subjected to an outlier correction: any responses exceeding the average response time ± 2 x standard deviation per subject and condition were removed. Reaction times to Go trials (since the correct response to No Go trials was no response, and thus no reaction time) were compared for excluded and included subjects with an independent sample t-test.

Error rates on No Go trials were calculated for each subjects by dividing the number of false alarms to No Go trials by the total number of No Go trials. An independent sample t-test was employed to test whether error rates on No Go trials differed between excluded and included subjects.

ERP data
The EEG signals were rereferenced off-line to the average of right and left mastoids, and an offline high pass filter of 0.1 Hz was applied. Blinks and eye movements were removed from the data using a procedure based on Independent Component Analysis (ICA) as described by Jung et al. (2000a,b). After that the data were segmented in epochs lasting from 250 ms before stimulus onset until 1000 ms after stimulus onset. After baseline-correcting the signals by subtracting mean amplitude in the 150 ms preceding stimulus onset, we eliminated segments in which the signal exceeded ±75 μV. As a result 28% of all trials were deleted in both conditions. For each participant the remaining artifact-free trials were averaged separately for Go and No Go trials.

Repeated-measure ANOVAs were used to compare the ERPs to Go and No Go trials in excluded and included subjects, with Cognitive Control (Go vs No Go) as a within subjects factor, and Exclusion (excluded vs included in Cyberball) as a between subjects factor. Univariate F tests with more than one degree of freedom in the numerator were adjusted by means of the Greenhouse-Geisser or Huynh-Feldt correction where appropriate. Uncorrected degrees of freedom and corrected P-values are reported.

RESULTS

Behavioral data
Excluded and included participants did not differ in their behavioral responses. Response times to Go trials were similar independent of whether people were excluded or included (M$_{\text{included}}$ = 382 ms, M$_{\text{excluded}}$ = 372 ms, t(30) = 1.01, P = 0.32, Cohen’s d = 0.36). Excluded participants were somewhat more likely than included participants to erroneously respond to No Go trials (a false alarm M$_{\text{included}}$ = 16%, M$_{\text{excluded}}$ = 21%). This difference in false alarm rates however was not significant (t(30) = 1.32, P = 0.20, Cohen’s d = .47).

ERP data
Figure 1 shows the ERPs evoked by predominant Go trials, in which participants had to press the spacebar, and much less prevalent No Go trials, which required no response, time-locked to the onset of the stimulus. The No Go trials, in which the participants needed to inhibit their predominant response, show clear electrophysiological differences from the Go trials. First, No Go trials evoke an increase in the N2 component, reflected by a significant main effect of Cognitive Control between 300 and 350 ms after stimulus onset [F(1,30) = 135.5, P < 0.0001, partial $\eta^2$ = 0.82]. This effect is followed by a larger P3 for No Go compared to Go trials, reflected by a significant main effect of Cognitive Control between 450 and 500 ms [F(1,30) = 103.5, P < .0001, partial $\eta^2$ = 0.82]. This clearly shows that exerting cognitive control leads to a clear pattern of neural responses, in the form of an N2 and P3 effect for No Go trials.

![Fig. 1 ERPs to Go (black line) and No Go (grey line) trials averaged over all participants. Inhibiting the response on the No Go trials evokes a large negative deflection between 250 and 350 ms, the N2, followed by a large positive deflection between 350 and 600 ms, the P3.](https://academic.oup.com/soc-cogn-affer/article/8/7/789/1655247/figdesc/97/1655247)
Subsequently, we tested whether Exclusion influenced the neural responses related to cognitive control. Figure 2 shows the difference waves of the ERPs for No Go–Go trials, such that the remaining activation represents the additional activation that is elicited by the conflict detection and response inhibition necessary in No Go trials. These difference waves are shown for the excluded and the included group. Figure 2 shows that No Go trials evoke an N2 effect and P3 effect in both excluded and included participants. However, these effects differ in size for the two groups. Excluded participants show a larger N2 effect than included participants, indicated by a significant interaction between Cognitive Control and Exclusion [averaged over all electrodes: $F(1,30) = 4.5$, $P = 0.04$, partial $\eta^2 = 0.13$]. This is followed by a smaller P3 effect for excluded compared to included participants, which is especially prevalent over parietal electrodes. This resulted in a trending interaction between Control and Exclusion averaged over all electrodes [$F(1,30) = 4.0$, $P = 0.054$, partial $\eta^2 = 0.12$] and a significant interaction between Control and Exclusion over parietal electrodes [averaged over CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, PO3, Po4: $F(1,30) = 6.36$, $P = 0.02$, partial $\eta^2 = 0.18$].

**DISCUSSION**

Participants who were socially excluded showed a larger N2 effect in trials where they had to inhibit a prepared response compared to non-excluded participants. This indicates that social exclusion makes people attribute more attention to the response conflict induced by No Go trials. The P3 effect, on the other hand, was smaller for excluded compared to included participants. This indicates that excluded participants exert less inhibitory control than included participants. Our results show that exclusion has a differential effect on the different sub-components of cognitive control: exclusion makes people invest more in the detection of a response conflict, but less in the actual inhibition of unwanted, impulsive responses.

Although exclusion has clear effects on the electrophysiological responses of the participants, the behavioral responses on the Go/No Go task do not seem to be influenced by exclusion. It could very well be that this is the case because the effects that show in the ERPs actually cancel each other out when it comes to behavioral outcomes on simple tasks: the combination of increased conflict detection (more cognitive control) and less inhibition (less cognitive control) in excluded participants could very well lead to a similar pattern of responses to the

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**Fig. 2** Difference waves (No Go–Go trials) for participants who experienced inclusion (black lines) and participants who experienced exclusion (grey lines). Both excluded and included participants show a distinct N2 and P3 effect. The N2 effect, however, is larger for excluded participants, while the P3 effect is smaller, especially over parietal electrodes.
included participants. On the other hand, experiments that have looked at the effects of negative mood and negative feedback on cognitive control have also observed a decoupling of behavior and brain responses (Hajcak et al., 2004; Wiswede et al., 2009).

The current results show that the behavioral consequences of exclusion, such as decreased impulse control and increased aggression could very well be determined by a decreased inability to inhibit responses. Our findings also provide a strong neural basis for a previous finding that exclusion alters cognitive control (Jamieson et al., 2010). This study showed that exclusion decreases the ability to inhibit automatic reflexive eye movements, but not the ability to correct those reflexive errors. When we combine these findings with our current results, a clear picture emerges of the effects of exclusion on cognitive control. On the one hand, exclusion leads to a decrease in impulse inhibition, signified by the decreased P3 reported here, and the inability to suppress automatic responses reported by Jamieson and colleagues (2010). On the other hand, exclusion does not change, or perhaps even stimulates, the overall ability to detect and correct conflicts and errors, as signaled by the increase in N2 effect for No Go stimuli, and the intact ability to correct errors in the antisaccade task (Jamieson et al., 2010).

The fact that we observed an increase in the N2 effect for excluded participants also shows that exclusion does not lead to decreased cognitive control on all fronts. Actually, the current results show that excluded people are better able to detect conflicts. Perhaps this ability to detect conflicting information, combined with a reduced inhibition lies at the basis of findings that exclusion does not always have detrimental effects on performance. For example Akinola and Mendes (2008) showed that people who experience social exclusion perform better on a creative task than included controls.

It has often been suggested that dealing with negative experiences such as social exclusion depletes the limited resources available to regulate behavior (Metcalfe and Mischel, 1999; Muraven and Baumeister, 2000; Fishbach et al., 2003; Gray, 2004; Ochsner and Gross, 2005). Indeed, imaging results indicate that social exclusion activates those brain areas that underlie cognitive control (Eisenberger et al., 2003), which suggest that social exclusion involves some level of emotion-regulation or control. However, the present results show that controlling the stress of social exclusion in itself does not drain all the resources available to subsequently control behavior. Instead the current results suggest that exclusion leads to a re-allocation of resources to specific sub-processes involved in cognitive control. This indicates that the behavioral consequences of negative experiences such as social exclusion do not need to be based on passive depletion of resources. Instead, those behavioral consequences might also be (partially) due to a rebalancing of priorities within the psychological system.

It thus seems that the profound experience constituted by social exclusion has very direct consequences for the basis of the ability to regulate behavior. The building blocks that constitute cognitive control are altered, even when subjects only experience exclusion in a virtual environment. This is important, because social exclusion is prevalent, for example within discrimination and humiliation, but it is often regarded as a very temporary state. Therefore, exclusion could be seen as relatively harmless. However, the current results show that the costs of social exclusion for the excluded might be a lot higher than just hurt feelings.

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