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Giving others the option of choice: An fMRI study on low-cost cooperation

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ABSTRACT

Successful social relationships require a consideration of a partner's thoughts and intentions. This aspect of social life is captured in the social mindfulness paradigm (SoMi task), in which participants make decisions that either limit or preserve options for their interaction partner's subsequent choice. Here we investigated the neural correlates of spontaneous socially mindful and unmindful behaviours. Functional magnetic resonance data were acquired from 47 healthy adolescents and young adults (age 16–27) as they completed the SoMi task. Being faced with socially relevant choices was associated with activity in the medial prefrontal cortex, anterior cingulate, caudate, and insula, which is consistent with prior neuroeconomical research. Importantly, socially mindful choices were associated with activity in the right parietal cortex and the caudate, whereas unmindful choices were associated with activity in the left prefrontal cortex. These neural findings were consistent with the behavioural preference for mindful choices, suggesting that socially mindful decisions are the basic inclination, whereas socially unmindful responses may require greater effort and control. Together, these results begin to uncover the neural correlates of socially mindful and unmindful choices, and illuminate the psychological processes involved in cooperative social behaviour.

1. Introduction

Social mindfulness is being thoughtful of others in the present moment, and considering their needs and wishes before making a decision. Recent research defined this novel construct as "making other-regarding choices involving both *skill* and *will* to act mindfully toward other people's control over outcomes" (Van Doesum et al., 2013, p. 86). Such choices are often made swiftly with little deliberation, and occur frequently in daily situations. Social mindfulness is focused on small stakes, such as acts of kindness or politeness, which may often serve social-communicative functions such as conveying interpersonal liking, closeness, or respect (Van Lange and Van Doesum, 2015). For example, imagine a father and his son having breakfast in a restaurant. As it happens, there are only three individual cups of strawberry and one cup of blackberry marmalade left to put on their toast. If the father decided to choose the unique item (i.e., the blackberry marmalade), he would literally remove the possibility of choice for his son; the latter can only have strawberry. This can be seen as socially unmindful. Choosing one of the non-unique items (strawberry), however, would be socially mindful, because it leaves the other more control over the outcome. In this case, the son would still be able to choose between two distinct options rather than just take or leave the single option. The opportunity to choose freely among many options is highly valued in our society (Aoki et al., 2014).

This example illustrates two important features by which the operationalisation of social mindfulness in the social mindfulness paradigm extends altruism and the traditional neuroeconomic games in research on cooperation (Camerer, 2003; Parks et al., 2013). First, social mindfulness captures the kind of low-cost (or "small stakes") cooperation that is so abundant in daily life: The son does not benefit greatly, nor does the father sacrifice much. Yet, the outcome of the situation determines important aspects of the interpersonal relationship. Despite its central role in everyday social life, such low-cost/small benefit cooperation has received relatively little attention (Van Lange and Van Doesum, 2015). The focus on low-cost cooperation is a useful complement to experimental research on economic games, which are

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designed to capture cooperation, often characterised by (substantial) losses and gains. The outcome differences in the social mindfulness paradigm are represented by minor differences in shape or colour of objects to choose from, but less so in acts that are associated with large losses or gains. Neither substantial amounts of money nor giving up important resources play a central role in this paradigm. As examined in the present research, social mindfulness involves choosing a redundant object so that the other person retains choice (i.e., opting for the unique marmalade would remove that choice for the other person). Investigating the neural correlates of socially mindful and unmindful behaviour may shed light onto which processes might underlie these forms of low-cost cooperation, thereby complementing the existing neuroeconomics and cooperation literature.

Second, social mindfulness targets a "social mind" that recognises the needs and wishes of others before deciding on one's actions. Social mindfulness is thought to be possible only when people are able to recognise that their choices affect the options for the other player, and have the will to act accordingly. In altruism and traditional economic games it is usually clear from the start that one's own choice impacts the other's outcomes; this is oftentimes mentioned explicitly in the instructions (Kahneman et al., 1986; Van Lange et al., 1997). However, in daily situations that is not always the case. The social mindfulness paradigm confronts participants with a situation in which choices need to be made, but *without* specific instructions regarding the outcomes of the other player in the task. This is left to the participants themselves (for details, see Methods, Section 2.2.1). Socially mindful behaviour thus requires a person to independently "see" that their decisions have consequences for others, which is a step beyond traditional approaches to cooperation.

To our knowledge, there is no research on the neuroscience of low-cost cooperation. Based on the existing literature on altruism and neuroeconomics using other paradigms (i.e., trust game, prisoners dilemma, and ultimatum game), where the goal and risks are usually clear, we investigated whether neural activity during the SoMi task is similar to these social decision making paradigms. As alluded to earlier, it is the combination of the absence of high risk, high cost, and large economic gain, reflecting every day choices and interactions, that inspired this new line of research. Our general hypothesis states that consistent forms of social mindfulness and unmindfulness activate neural areas that are also implicated in deliberate forms of social decision making, including the dorso-lateral and medial prefrontal cortex (dlPFC and mPFC: (Amodio and Frith, 2006; Badre and Wagner, 2004; Mitchell et al., 2009; Ridderinkhof et al., 2004; Van Overwalle, 2009)). Furthermore, considering the needs and wishes of others is thought to involve mentalising, perspective-taking, and empathy, reflecting the *skill*. The neural mechanisms of perspective-taking and empathy have been extensively studied (Decety, 2011; Gallagher and Frith, 2003; Schurz et al., 2014; Shamay-Tsoory, 2011), but it is the combination of both seeing another's (subtle) preference, and acting upon it in other-regarding manner, that is essential to social mindfulness. Brain areas such as the anterior cingulate (ACC), mPFC, temporo-parietal junction (TPJ) and insula are involved in these processes (Blakemore, 2008; Contreras et al., 2013; Saxe and Wexler, 2005; Zhu et al., 2007). Lastly, we hypothesise that affect is a key aspect of social mindfulness, including sensations of reward. Based on this reasoning, we also expect to find activation of the ventral striatum, caudate, and insula (Delgado, 2007; Duerden et al., 2013; Hackel et al., 2015; Knutson and Cooper, 2005; Menon and Uddin, 2010; Rilling and Sanfey, 2011). It is plausible that doing good, being considerate of the other person, brings about a sense of reward (Higgins and Scholer, 2009), but perhaps choosing the unique and therefore more valuable item (Brock, 1968; Lynn, 1991) might be rewarding too (Higgins and Scholer, 2009). In another study using this paradigm, social mindfulness was investigated between friends and foes (Van Doesum et al., 2016), showing that taking away the choice for the other might be rewarding under certain circumstances (with foes). Therefore, we also examined differences between socially mindful or unmindful choices, and investigated which choices could be considered the basic inclination. In addition, mirroring the conceptualisation of social mindfulness (Mischkowski et al., 2017; Van Doesum et al., 2017, 2013; Van Lange and Van Doesum, 2015), associations of brain activity and measures of prosociality (the *will*) and the Reading the Mind in the Eyes Task (the *skill*) (Baron-Cohen et al., 2001) were investigated to strengthen our inferences regarding underlying mechanisms.

2. Methods

2.1. Participants

Fifty-three healthy adolescents and young adults, aged 16–27, were recruited at schools and universities in the wider Amsterdam area (The Netherlands). Inclusion criteria were age between 16 and 31 and sufficient command of the Dutch language. Exclusion criteria were a family history of psychiatric disorders, autism spectrum disorders, an IQ < 80 (approximately) and any contraindications for MRI scanning. All participants provided written informed consent. Six participants were excluded from analyses due to invalid data, leaving us with a sample of 47 subjects (22 female, M_{age} = 21.13, SD = 2.69). This research was approved by the Ethical Committee of the VU Medical Center Amsterdam.

2.2. Measures

2.2.1. Social Mindfulness Paradigm (SoMi task)

The SoMi task requires that the participant and a (fictitious) second person each choose one item from a set of four among which one is unique and the rest identical (e.g., three green apples and one red apple, see Fig. 1) (Van Doesum et al., 2017). The paradigm has been

Fig. 1. Example trials of the social mindfulness task (SoMi), displaying (a) an experimental trial (3:1 ratio presentation) and (b) a control trial (2:2 ratio presentation). The stimulus was displayed for 5000 ms, followed by an inter-stimulus interval (0, 1000, or 2000 ms).Taken with permission from ms). Van Doesum et al. (2016).

well validated (Van Doesum et al., 2013), and social mindfulness has already exhibited reliable associations with self-reports of empathy, perspective-taking, honesty, and prosocial orientation (Mischkowski et al., 2017; Van Doesum et al., 2013, 2016). Participants were instructed that they would always choose first, and that chosen items would not be replaced. Choosing an identical item, and thereby leaving the second person a choice, was labeled socially mindful; taking away the unique item, and thus limiting this other person's choice, was labeled socially unmindful. We introduced control trials as a baseline measure for fMRI analyses, displaying the items in a 2:2 ratio (e.g., two blue and two yellow base-ball caps), in which the participant's choices would have no social consequences.

Using a within-participants design, the SoMi task was administered twice. In the first round (spontaneous condition), participants only received the above-mentioned general information. In the second round (instructed condition), participants received the instruction to "keep the best interest of the other person in mind" (cf. Van Doesum et al., 2013). Note that the instructions we used provided directional information only: Participants were not *explicitly* asked to behave in a socially mindful manner. Instruction was included for replication of previous behavioural studies (Studies 1a-1c, Van Doesum et al., 2013), and to examine whether results of the current sample were similar to previous samples. In the fMRI analyses, however, only spontaneous choices were used, because spontaneous (un)mindful choices were our main interest, and all participants chose predominantly mindfully after instruction, making the unmindful sample too small for reliable analyses.

Each round consisted of 60 trials, including 24 experimental trials, presenting one unique versus three identical items and 24 control trials, offering two pairs of identical items. Experimental and control trials were presented in a quasi-randomised order that was identical for all participants. The stimulus was presented for 5000 ms. During this period participants had to make a choice, which was immediately made visible to the participant. After 5000 ms an inter-stimulus interval (blank screen) followed, randomly jittered between 0, 1000, and 2000 ms. Additionally, 12 null events were randomly inserted with a duration of 5000 ms, where participants passively watched a blank screen. Mindful answers were equally distributed over the four answer options, using the index and middle fingers of both hands.

In addition to providing a context to examine socially mindful and unmindful decisions, task behaviour yielded an index of participants' degree of social mindfulness. This SoMi index was computed as the proportion of socially mindful decisions, varying from 0 (only socially unmindful choices) to 1 (only socially mindful choices). For behavioural analyses, the number of choices made (mindful and unmindful) and reaction times (stimulus onset to participant's choice) were examined.

2.2.2. Social Value Orientation (SVO)

Social value orientation is thought to reflect the *will* to act in a socially mindful manner and is used as potential moderator for socially mindful behaviour. We measured SVO with the well-validated nine-item Triple Dominance Measure (Haruno and Frith, 2010; Van Lange et al., 1997). Participants were asked to allocate valuable points (money) between themselves and an unknown other. They could choose for a division (a) of equal amounts (e.g., 520–520), (b) with greatest gain for themselves (e.g., 580–320), or (c) with maximum difference between self and other (e.g., 520–120). Participants were classified as having (a) a prosocial orientation, preferring equality in outcomes; (b) an individualistic, or (c) a competitive orientation, enhancing absolute or relative advantage for the self, respectively, only if they made six or more choices within one category. With less than six answers within one category, the participant was considered unclassifiable (Van Lange et al., 1997) and was excluded from analyses involving SVO ($n = 5$). Because we found relatively few participants with individualistic ($n = 9$) and competitive ($n = 3$) orientations in our sample, we collapsed these two categories into a proself ($n = 12$) orientation, to be contrasted with the prosocial ($n = 30$) orientation, treating SVO as a dichotomous variable, see also (De Cremer and Van Lange, 2001; Van Kleef and Van Lange, 2008).

2.2.3. Reading the Mind in the Eyes Task (Eyes task – adult version)

The ability to understand the mental states of other persons is thought to be involved in social decision making (the *skill* needed to act in a socially mindful way). The Eyes task is a 28-item questionnaire used to test an aspect of Theory of Mind ability (Baron-Cohen et al., 2001; Vellante et al., 2013). On each trial, a pair of eyes was presented on the computer screen, and four emotional expressions were presented below it. Participants were instructed to choose the emotional expression that best fitted with the pair of eyes shown. This task involves inferring mental states of an individual from information based on a picture of their eyes. The proportion of correct answers was calculated. Reaction times were not recorded and no time limit was imposed.

2.3. Procedure

After signing the consent form, participants completed several pen and paper questionnaires - unrelated to this topic - followed by the Eyes task and the SVO assessment on a computer. Subsequently participants were scanned for 55 min. The scanning session started with a trust game, with no final gain displayed at the end (Lemmers-Jansen et al., 2017). To limit possible transfer-effects to the second paradigm, the trust game was followed by the structural scan, during which participants could relax for 6 min closing their eyes or watching a movie. Thereafter, participants completed the SoMi task, lasting approximately 15 min. Instructions were provided in the scanner, immediately prior to the task. Four practice trials were completed to ensure understanding of the task. Instructions for the second round were given visually and orally while scanning was paused. After scanning, participants received an image of their structural brain scan, €25 for participation, and travel expenses.

2.4. fMRI data acquisition

fMRI data were obtained at the Spinoza Center Amsterdam, using a 3.0T Philips Achieva whole body scanner (Philips Healthcare, Best, The Netherlands) equipped with a 32 channel head coil. A T2* EPI sequence (TR = 2, TE = 27.63, FA = 76.1°, FOV 240 mm, voxel size 3 × 3 × 3, 37 slices, .3 mm gap) was used, resulting in 185 images per condition. A T1-weighed anatomical scan was acquired for anatomical reference (TR = 8.2, TE = 3.8, FA = 8^0, FOV 240*188 mm, voxel size 1 × 1 × 1, 220 slices).

2.5. Data analysis

2.5.1. Behavioural data

Demographic and behavioural data were analysed using Statistical Package for the Social Sciences (SPSS, 2012). Paired samples *t*-tests were used to analyse the frequency of choices participants made and differences in reaction times (RT) between conditions. Pearson correlation was used to test the association between RT, choice patterns, and Eyes task. For the associations between RT and choice patterns, and the dichotomous variable SVO, a point-biserial correlation was used.

2.5.2. Imaging data

Imaging data were analysed using Statistical Parametric Mapping 8 (SPM, 2009). Functional images for each participant were preprocessed with the following steps: realign and unwarp, coregistration with individual structural images, segmented for normalisation to an MNI template and smoothing with a 6 mm full width at half maximum (FWHM) Gaussian kernel. At first-level, a general linear model (GLM) was used to construct individual time courses for the onset of trial presentations and individual reaction times for the spontaneous and instructed conditions. The interval between stimulus onset and choice time represented the decision period, which was modelled with a delta function modulated by the actual reaction times. The combination of mean reaction times around 2000 ms (with small variations) and the inter-stimulus interval (0, 1000, 2000 ms) ensured enough time (3000–5000 ms) to distinguish between subsequent trials (Friston et al., 1999). Experimental trials were contrasted with the control trials (2:2 ratio), the baseline measure. In the experimental trials (3:1 ratio), a distinction was made between socially mindful and unmindful responses. At second level, a one-sample *t*-test was used for the main effects, followed by conjunction analyses, to determine overlap in activation between mindful and unmindful choices, and exclusion analyses to identify choice specific neural activation. All analyses were controlled for age and gender effects.

To ensure reliable neural analyses of responses in the experimental trials, for fMRI analysis participants were only included in the analysis of a condition if they had at least 1/3 of the 24 responses within that condition. Participants with 1–7 unmindful responses were included only in the mindful condition, with 8–16 unmindful choices were included in both mindful and unmindful conditions, and with 17–24 only in the unmindful condition. This resulted in varying sample size per analysis. In the analysis where participants were presented with an experimental trial per se (3:1 ratio presentation, i.e., making a social choice), all responses of all participants were included.

A whole brain analysis was performed to identify general patterns of task activation. First, we looked at the general condition of being presented with an experimental trial (social choice), regardless of outcome (spontaneous mindful and unmindful answers > control trials). Then spontaneous mindful choices > control trials and unmindful choices > control trials were analysed separately. All main effects were calculated at a significance level of $\alpha = .05$ whole brain family-wise error (FWE) corrected. Conjunction and exclusion analyses were also conducted at a significance level of $\alpha = .05$ whole brain FWE corrected. For these analyses, one condition (e.g. mindful choices > control) was selected, and a contrast calculated with the other condition (e.g. unmindful > control) with a mask *p*-value of .05. The mask was inclusive for conjunction analyses, showing regions that were activated in both conditions, and exclusive for exclusion analyses, showing condition specific activation. For the whole brain FWE corrected analyses no additional cluster size threshold was used.

Second, exploratory conjunction and exclusion analyses were performed with SoMi index and Eyes task as covariates. These behavioural measures were added to identify mechanisms underlying this paradigm. Procedure was similar to the above mentioned conjunction and exclusion analyses, however, these analyses were performed with a more lenient threshold of $p = .001$ uncorrected, using a cluster size threshold of $k = 10$.

3. Results

3.1. Behavioural results

Participant characteristics are displayed in Table 1. Analysing the choice pattern of the 47 participants in the SoMi task, the number and proportion of mindful and unmindful responses were calculated (see Table 2). Paired samples *t*-tests showed that, in the spontaneous condition, participants made significantly more mindful than unmindful choices overall, $t(46) = 2.73$, $d = .4$, $p = .009$ (*M* proportion mindful, unmindful = .56, .44). These proportions differed significantly from chance, $t(46) = 2.56$, $d = .4$, $p = .014$. As expected, participants were more likely to make mindful choices in the instructed condition $t(46) = 8.78$, $d = 1.3$, $p < .001$ (*M* proportion spontaneous, instructed: .56, .86), confirming that the instruction had the intended effect. Males and females did not differ significantly in age, SVO nor in the number of spontaneous mindful choices.

Table 1
Participant characteristics.

Participants, *N*	47
Age, mean (*SD*), range	21.13 (2.69), 16.2–27.4
Gender, male *N* (%)	25 (53%)
Handedness, right handed *N* (%)	38 (81%)
SVO, prosocial / proself / no category *N* (%)	30 (64%) / 12 (25%) / 5 (11%)
Eyes task, proportion correct answers (*SD*)	.69 (.1)

Note: SVO = Social Value Orientation; Eyes task = Reading the Mind in the Eyes task.

Table 2
Behavioural outcomes of the social mindfulness task.

Number of Recorded Choices per Condition	Spontaneous *n (SD)*	Instructed *n (SD)*
Mindful	13.36 (3.64)	20.74 (4.36)
– proportion	.56 (.15)	.86 (.18)
Unmindful	10.47 (3.64)	3.26 (4.36)
– proportion	.44 (.15)	.13 (.18)
Mean Reaction Times per Condition in Milliseconds	*M (SD)*	*M (SD)*
Mindful	1975.17 (422.50)	1583.43 (325.22)
Unmindful	2009.97 (434.54)	1870.43 (677.69)

Note: Number of choices made between conditions (spontaneous and instructed) and between choices within condition (mindful and unmindful), all differences were significant at $\alpha = .001$. RT in the instructed mindful condition differed significantly from spontaneous mindful choices ($\alpha = .001$) and from instructed unmindful choices ($\alpha = .05$).

Reaction times (RT) for spontaneously mindful and unmindful choices were not significantly different ($p = .51$; for means, see Table 2). A paired samples *t*-test showed a significant decrease of reaction times for mindful choices after instruction, $t(46) = 7.94$, $p < .001$. After instruction, RT for unmindful choices remained unchanged.

The mean proportion of correct answers for the 47 subjects on the Eyes task was .69 ($SD = .10$) and the distribution of the SVOs was comparable to previous research, with more prosocial ($n = 30$) than proself oriented participants ($n = 12$; 5 participants were not categorisable due to inconsistent decisions) (Van Lange et al., 1997; Van Doesum et al., 2013).

3.2. Associations

Correlation and point-biserial correlation analyses were performed to investigate the association of Eyes task and SVO (believed to represent the *skill* and *will* underlying SoMi) with the SoMi task outcomes. As expected, SVO was associated with the proportion of spontaneous mindful choices: Prosocial individuals made more mindful choices ($M = .59$), and proselfs made more unmindful choices ($M = .48$, $F[1,40] = 5.09$, $p = .030$). This pattern validated our interpretation of task responses as indicating mindful and unmindful responses, respectively. Eyes task outcome was not significantly associated with the proportion spontaneous mindful choices ($p = .62$), nor with reaction times (all *ps* > .47).

Associations of RT with the Eyes task and SVO were not significant (all *ps* > .33) and no differences within SVO group between RT for mindful and unmindful choices were found. Having a proself orientation did not result in faster unmindful decisions.

3.3. fMRI results

3.3.1. Whole brain results

All main effects were calculated with an FWE corrected significance level of $p = .05$. Experimental trials were contrasted with the control trials. After initial analyses, one participant was classified as an outlier on the basis of the β-values exceeding 3 SDs from the mean. This

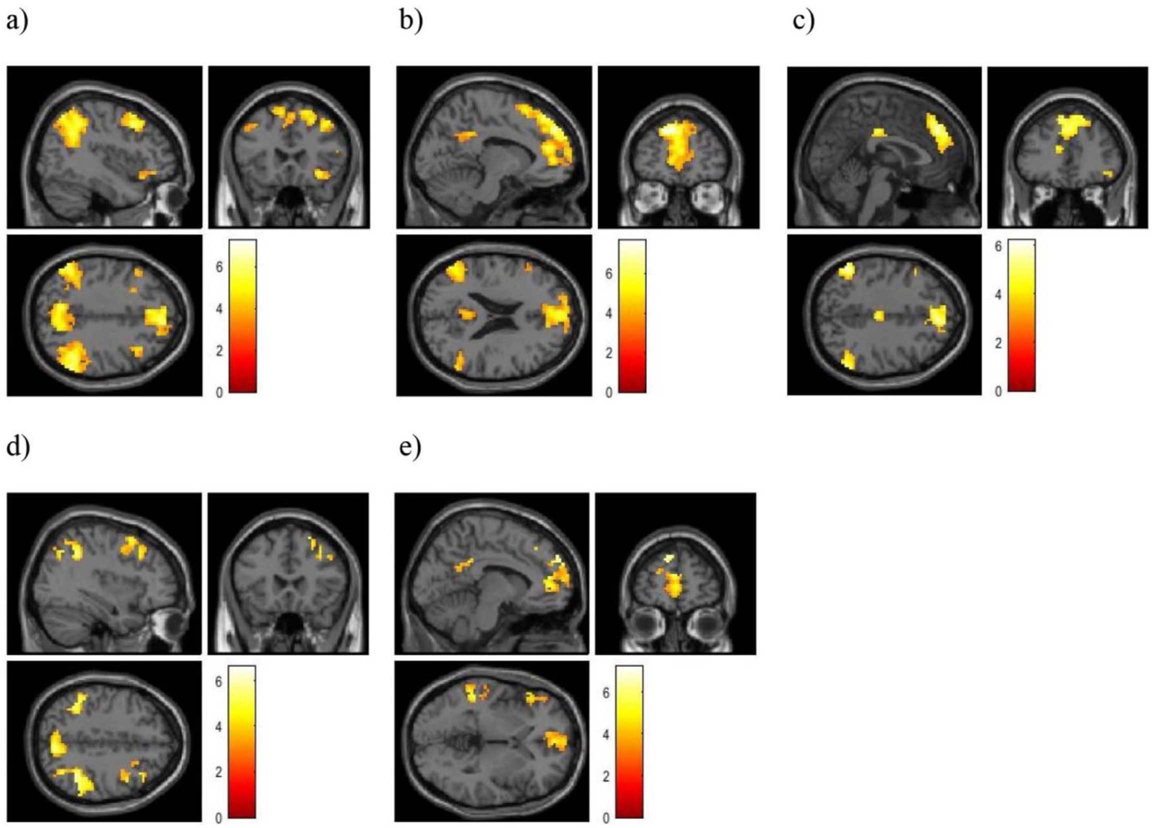

Fig. 2. Whole brain results for a) spontaneous socially mindful choices > control trials ($n = 43$), and b) spontaneous socially unmindful choices > control trials ($n = 37$), and c) the conjunction analysis, followed by d) exclusion analyses mindful choices > control trials excluding unmindful choices > control trials, and e) unmindful choices > control trials excluding mindful choices > control trials. For the images results were displayed with an uncorrected $p = .001$, with a cluster size threshold of k = 50.

participant was removed from all fMRI analyses, resulting in a sample of $N = 46$. Presentation of an experimental trial, a choice with social consequences (experimental trial > control trial; $N = 46$), was associated with robust medial prefrontal and parietal activity, together with posterior cingulate cortex (PCC) and precuneus activity (see Supplementary Table 1). The main effect of making spontaneously mindful choices (mindful > control; $n = 43$) elicited bilateral activation in frontal, temporal, and parietal areas, including the middle and posterior cingulum (see Fig. 2a and Supplementary Table 2). Making spontaneously unmindful choices (unmindful > control; $n = 37$) was associated with activation in bilateral prefrontal and parietal areas, as well as the ACC, PCC and insula (see Fig. 2b and Supplementary Table 3).

The overlap between mindful and unmindful choices and choice specific activation were tested to examine general patterns of activity for the SoMi task and activation unique to each response. Conjunction analysis showed bilateral TPJ and midline (pre)frontal activation (see Fig. 2c and Table 3). Specific activation for mindful choices (mindful > control excluding unmindful > control) was found in the right hemisphere, in frontal and parietal areas, including TPJ (see Fig. 2d and Table 4). The analysis of the reverse contrast (unmindful > control excluding mindful > control) revealed activation in the left hemisphere, mainly frontal, in the mPFC, ACC and superior frontal gyrus, as well as temporal regions and PCC (see Fig. 2e and Table 4). Lateralisation shows clearly in Table 4, but is less clear in Fig. 2d and e, due to a more lenient threshold.

3.3.2. Associations between neural activity, SoMi index, and Eyes task

Exploratory exclusion and conjunction analyses were performed with SoMi index and Eyes task to investigate their associations with neural activity. Only in the mindful choices > control excluding unmindful > control associations were found (see Table 5). SoMi index was uniquely associated with activation of the caudate, temporal middle gyrus, postcentral gyrus, and the cerebellum. Eyes task showed an association with dlPFC activation. Associations of the SoMi index with caudate activity and Eyes task with dlPFC are displayed in Fig. 3. The reverse analysis (unmindful > control excluding mindful > control) and the conjunction analysis did not reveal significant associations with SoMi index nor Eyes task.

Table 3
Conjunction between spontaneous mindful and unmindful choices.

Overlap Mindful and Unmindful	Hemisphere	MNI coordinates			Cluster size	*p*	*z*
		x	y	z			
mPFC	R	3	41	40	26	.001	5.54
ACC	R	3	50	34			5.08
mPFC	L	−6	41	46	3	.006	5.04
mPFC	R	0	35	46	1	.017	4.76
Superior frontal gyrus	R	15	44	46	2	.009	4.73
TPJ	L	−51	−58	37	39	< .001	5.57
	L	−51	−58	28			4.93
TPJ	R	57	−61	34	4	.003	4.85
TPJ	R	48	−58	31	1	.017	4.86

Note: Conjunction analyses were performed with a $p = .05$, whole brain FWE corrected, with a contrast mask p-value of .05, and no additional cluster size threshold. Results show brain areas that are activated in both mindful > control and unmindful > control conditions. TPJ = temporo-parietal junction; mPFC = medial prefrontal cortex; ACC = anterior cingulate cortex; R = right; L = left.

Table 4
Condition specific results for the mindful and unmindful choices.

	Hemisphere	MNI coordinates			Cluster size	*p*	*z*
		x	y	z			
Mindful							
Superior frontal gyrus	R	21	20	58	5	.002	5.31
Inferior parietal gyrus	R	51	−43	49	62	< .001	5.86
TPJ	R	42	−49	46			5.39
TPJ	R	60	−49	31	8	.001	5.02
Inferior parietal gyrus	L	−36	−49	43	8	.001	5.06
Inferior parietal gyrus	L	−48	−43	43	2	.009	4.84
Temporal middle gyrus	R	57	−58	13	1	.017	5.01
Precuneus	L	−9	−70	37	3	.006	4.94
Cuneus	R	9	−70	37	27	< .001	5.23
Unmindful							
Superior frontal gyrus	L	−15	53	34	23	< .001	6.27
mPFC	L	−9	59	31			5.85
mPFC	L	−3	62	16	23	< .001	5.53
ACC	L	−6	47	13	19	< .001	5.62
	L	−9	47	4			5.09
ACC	L	−3	41	19	1	.017	4.85
ACC	R	0	53	1	1	.017	4.76
Superior frontal gyrus	L	−15	35	46	5	.002	5.00
PCC	L	−3	−37	31	6	.001	5.50
PCC	L	−3	−49	25	4	.003	4.91
Temporal middle gyrus	L	−54	−16	−11	4	.003	5.35
Temporal middle gyrus	L	−51	−37	−2	5	.002	4.99
Temporal middle gyrus	L	−63	−19	−8	1	.017	5.06

Note: Exclusion analyses were performed with a $p = .05$, whole brain FWE corrected, with a contrast mask p-value of .05, and no additional cluster size threshold, showing condition specific activation for the mindful > control excluding activation in the unmindful > control condition, and the reverse, unmindful > control excluding activation in the mindful > control condition. TPJ = temporo-parietal junction; mPFC = medial prefrontal cortex; ACC = anterior cingulate cortex; PCC = posterior cingulate cortex; R = right; L = left.

4. Discussion

The purpose of the present research was to examine the neural substrates of socially mindful and unmindful behaviour, a phenomenon in social decision making that is gaining more and more attention. By unraveling the underlying neural networks of social mindfulness, we aimed to verify social psychological theories of social mindfulness, conceptualised in terms of skill and will to act in an other-regarding manner. The social mindfulness task involves a series of choices for objects, that may have implications for the options that are left for the next person. This SoMi task is increasingly used in behavioural experiments, and allowed us to examine low-cost cooperation in a naturalistic context. In this task people typically need "to see" the social (un)mindfulness of the options to act upon it in a purposeful manner. Three main findings of the present research can be highlighted: (1) Socially relevant decisions in the SoMi task, compared with responses that did not have implications for social mindfulness, involve medial prefrontal and (medial) parietal activity, resembling activation in other neuroeconomic games; (2) spontaneously, participants made more often mindful than unmindful choices, and socially mindful and unmindful decisions activated different areas and networks, suggesting distinct underlying mechanisms; and (3) results were partly moderated by SoMi index, the mindful behaviour.

As we discuss below in Section 4.3, these findings are consistent with the view that socially mindful choices activate a more automatic network (Lieberman, 2007; Sanfey and Chang, 2008; Spitzer et al., 2007), suggesting that participants were generally more automatically inclined to make mindful choices. Inferring processes from observed neural activation is speculative (Poldrack, 2006; Poldrack et al., 2016). However, we link the present findings to previous research and

Table 5
Associations of SoMi Index and Eyes task with brain activation.

Condition	Covariate	Hemisphere	MNI coordinates			Cluster size	*z*
			x	y	z		
Mindful	*SoMi index*						
Caudate		L	−18	20	1	14	3.88
			−15	14	7		3.56
Temporal middle gyrus		R	54	−58	7	16	3.84
Postcentral gyrus		L	−39	−13	34	27	3.69
			−39	−22	34		3.30
Cerebellum		L	−24	−67	−29	10	3.60
Cerebellum		R	15	−61	−17	13	3.53
			15	−61	−26		3.33
Mindful	*Eyes task*						
dlPFC		R	48	20	4	14	3.83
			45	26	−2		3.79

Note: Exploratory analyses were performed to investigate associations with the covariates SoMi index and Eyes task. Exclusion analyses were performed with a $p = .001$ uncorrected, using a contrast mask p-value of .05, and a cluster size threshold of k = 10, showing condition specific activation for the mindful > control excluding activation in the unmindful > control condition, for SoMi index and Eyes task. SoMi index = proportion socially mindful choices; Eyes task = Reading the Mind in the Eyes task; dlPFC = dorso-lateral prefrontal cortex; R = right; L = left.

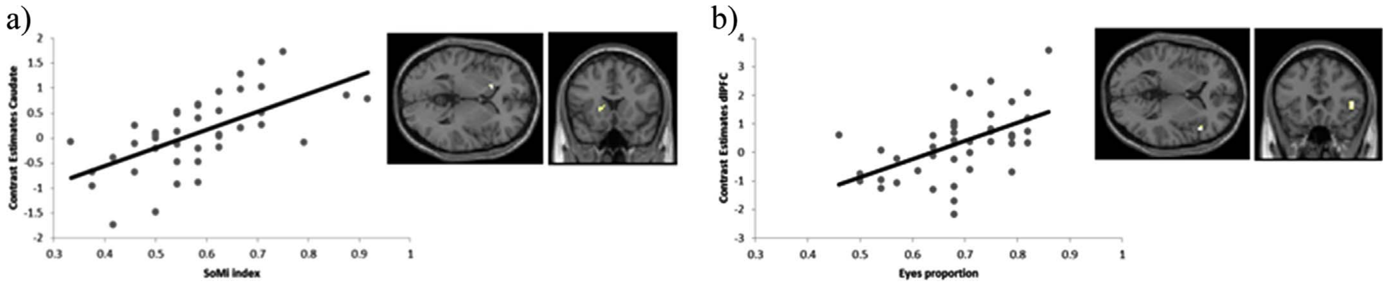

Fig. 3. Associations between neural activity and behavioural measures are shown for a) the left caudate (coordinates: −18, 20, 1) showing associations with behavioural outcome of the social mindfulness task (SoMi index), and b) the right dorsolateral prefrontal cortex (dlPFC; coordinates: 48, 20, 4) with the proportion correct answers of the Reading the Mind in the Eyes task (Eyes task).

behavioural data, which implicated similar regions and networks in social decision making tasks (Tabibnia and Lieberman, 2007). The present neural findings add to the behavioural findings by contributing to a theoretical framework for social mindfulness and complementing the literature on low-cost cooperation.

4.1. Socially relevant decisions

The first observation is that making social decisions in the SoMi task relates to medial prefrontal and (medial) parietal activity, activating a wide range of social brain areas reported in studies using other neuroeconomic paradigms, including mPFC, ACC, TPJ, caudate, precuneus, and insula (Bellucci et al., 2016; Güroğlu et al., 2010; King-Casas et al., 2005; Lemmers-Jansen et al., 2017; Sanfey et al., 2003; Spitzer et al., 2007; Tabibnia and Lieberman, 2007; van den Bos et al., 2009). The present findings show that the mere presence of even low-cost forms of cooperation can activate social decision making and mentalising areas. Specifically, merely facing a conflict between a socially mindful and a socially unmindful option seems to activate brain areas that are consistent with the concept of a *social mind* as captured by the construct of social mindfulness (Van Lange and Van Doesum, 2015).

4.2. Comparing socially mindful and unmindful choices

At the behavioural level, participants spontaneously made more socially mindful than unmindful choices, suggesting a preference to act mindfully. This observation was, however, not supported by differences in reaction times. The proportion of mindful choices and the classification of SVO (almost twice as much prosocials than proselfs) are in line with a previous study, but proportionally the current sample made less socially mindful choices (cf. Study 4, Van Doesum et al., 2013). We should note, however, that the behavioural differences (56% mindful, 44% unmindful choices) do not yet allow us to draw any firm conclusions about the general preferred mode of responding.

At the same time, personal preferences were apparent: In line with previous research, an association of SVO and SoMi index was found, indicating that prosocial individuals spontaneously made more socially mindful choices than did proselfs (Van Doesum et al., 2013). Instruction to be other-oriented increased socially mindful choices (cf. Studies 1a-1c, Van Doesum et al., 2013), especially for participants who spontaneously made less mindful choices. This observation may be partly due to a ceiling effect, but it indicates that instruction also is effective for participants who were not automatically mindfully inclined: All participants were able to display socially mindful behaviour when instructed. This finding suggests that spontaneous mindful choices were based on intentions to behave prosocially. Underlying mechanisms that are often associated with neuroeconomic paradigms such as risk taking or inequity aversion, fairness and punishment are less applicable to this paradigm. Furthermore, instruction made reaction times shorter for socially mindful choices, but not significantly for socially unmindful choices. This pattern may suggest that socially mindful responses became more automatic: Participants were following an instruction instead of actively making decisions. Alternatively, being in a mindful environment (after instruction), answering within the habitual response shortened RT, resulting in faster, more automatic mindful responses.

Whole brain analysis revealed that neural activation when making spontaneous mindful decisions resembled the frontoparietal network (FPN). The FPN is engaged in various cognitive processes, such as planning and cognitive control (Spreng et al., 2010), directing attention, and weighing behavioural choices (Seeley et al., 2007). With these functions, the activation of the FPN would fit in both mindful and unmindful decisions. However, an additional function during decision making, integrating information from the external environment with stored internal representations (Vincent et al., 2008) corresponds better with the mindful condition. This function is in concordance with the idea that when acting socially mindfully, one considers the options in light of the consequences for the other. Exclusion analyses revealed mindful specific activation predominantly in the right hemisphere and in the parietal lobe. The activation of the TPJ in mindful choices fits the idea of more outward oriented mentalising processes (Frith and Frith, 2006), supporting the other-focused orientation in mindful decisions.

Making spontaneous socially unmindful choices showed an activation pattern similar to the default mode network. Interpreting the activation in light of spontaneous internal cognition, self-referential thoughts, and processing of self-promotion goals (Spreng et al., 2010), we can speculate that making unmindful choices involves self-reflective thought and judgments, including moral decisions (Buckner et al., 2008; Greene et al., 2001). Exclusion analysis supports this idea, showing predominantly frontal activation, only in the left hemisphere (Amodio and Frith, 2006; Frith and Frith, 2006). Choosing the unique item seems to be more deliberate and self-reflective than making socially mindful decisions.

4.3. Associations with SVO, SoMi index and Eyes task

The third observation concerns the association of SVO, SoMi index, and the Eyes task (the operationalised *skill* and *will*) with task outcome and neural activation. A prosocial orientation was associated with more spontaneous mindful choices. SVO has often been studied as a moderator variable, for example showing that prosocials are more likely to cooperate than proselfs, even if they themselves do not directly benefit by doing so, whereas proselfs only tend to show some cooperation when there is a future in which they can benefit from cooperation (Van Lange et al., 2011). Focusing on regions associated with social decision making, exploratory brain analyses showed that the proportion mindful choices was associated with the activation of the caudate, a region involved in goal-directed behaviour in order to obtain reward (Grahn et al., 2008), reward processing (Rilling et al., 2002; Rilling and Sanfey, 2011), and even norm compliance (Spitzer et al., 2007). Its activation and the association with the SoMi index may indicate that choosing the socially mindful option brings about gratifying emotions, suggesting that for those inclined to choose mindfully, this choice is rewarding.

Moreover, the better participants were at performing the mentalising task, the more dlPFC activation during mindful choices was observed. The dlPFC is implicated in flexible decision making and resolving conflict (Mitchell et al., 2009), cognitive control (Cieslik et al., 2012), associated with fairness goals (Knoch et al., 2006), value processing (Dixon and Christoff, 2014; Hare et al., 2009), and manipulation of verbal and spatial knowledge (Barbey et al., 2013). However, the most plausible explanation in combination with higher mentalising scores would be the implementation of fairness norms (Spitzer et al., 2007), possibly in combination with overriding prepotent selfish responses (Rilling and Sanfey, 2011). However, the latter explanation is conflicting with our finding that making mindful choices seems to be the automatic, therefore prepotent response. The better a participant is in mentalising, the more the consequences for another person are considered during mindful decision making. These analyses are, however, reported at a more lenient threshold of $p = .001$ uncorrected, and should therefore be interpreted with caution.

The present findings suggest that distinct networks play a role during mindful and unmindful choices, and add neuroscientific evidence in support of a motivational difference. We suggest that people with a prosocial orientation are more likely to automatically act in a socially mindful manner, and that mindful choices may well be the result of relatively automatic, rewarding, and less controlled decision making (Rand et al., 2012; Rand and Nowak, 2013; Sanfey and Chang, 2008). In contrast, people with a proself orientation may closely evaluate the strategic advantages of social mindfulness (Van Lange et al., 2011), possibly reflected by increased prefrontal activation, suggesting a more effortful process. These findings suggest new predictions that could be tested more directly in future research.

5. Limitations and future directions

The present study provides an initial investigation of the neural underpinnings of socially mindful and unmindful behaviour. Although our results provided important new contributions to our understanding of social mindfulness in the context of social decision making, it is important to consider some of the limitations and boundary conditions in this work. The first limitation is that we did not include qualitative data on subjects' motivations for decision making. As discussed in Section 4.3, motivations for social interactions differ between prosocially and proself oriented participants. We can only hypothesise the difference in motivation on the basis of the neural results, suggesting different underlying mechanisms. If participants are indeed conscious of their motivations, such data (additional questionnaire after administering the SoMi task) would be a valuable addition to future SoMi research. A distinction with norm compliance and other educationally imposed behaviours could then be made. Secondly, participants were scanned for about an hour, which could have caused fatigue. However, it has been shown that cognitive load and time pressure do not affect socially mindful behaviour (Mischkowski et al., 2017), but may have affected neural outcomes. In addition, the lateralised specific brain activity for mindful and unmindful choices might have been influenced by the inclusion of left handed participants (Willems et al., 2014).

Furthermore, we were not able to establish a direct relation with mentalising abilities as assessed with the Eyes task. Like much past fMRI work, our conclusions about mentalising were based on reverse inference (Amodio, 2010; Poldrack, 2006; Poldrack et al., 2016). Performing both SoMi and mentalising tasks in the scanner, and including reaction times for the mentalising task could reveal valuable, direct information about this relation. Possibly with another task (e.g., the director task (Dumontheil et al., 2010); or the hinting task (Corcoran et al., 1995)), investigating other aspects of mentalising and perspective taking, links between SoMi and mentalising could be specified and the differentiation of the mentalising network further explored. A broader age range would also add to the present knowledge by yielding information about the window of development of SoMi, hypothesising that after a period of development, increases in social mindfulness would level off (Crone and Güroglu, 2013). Girls have been found to be more prosocial than boys, with a preference for empathy rather than competition (Derks et al., 2015). Gender differences might also play a role in the SoMi task, hypothesising more spontaneous mindful choices in females than in males. To further increase similarities with existing paradigms, making the SoMi task really interactive, in the sense that choice feedback is given or participant acting as second chooser, would add to the concept of social mindfulness, both when given and received. And lastly, administering the SoMi task to patient groups that suffer from social deficits (e.g., autism spectrum disorder and psychosis) could shed light on the importance of mentalising and basic prosocial orientation on social interactions. It may well be the recognition of "subtle consequences for others" that is easy to learn (instruct) but often overlooked in theory and research on human cooperation

5.1. Concluding remarks

The present study helps to substantiate the novel construct of social mindfulness by investigating its neural underpinnings. Social mindfulness involves relatively subtle consequences for others with substantial impact on the interpersonal relationship. In the context of the growing research on social mindfulness in various social domains like aggression (Van Doesum et al., 2016), perceived customer mistreatment (Song et al., 2017), or the influence of social class on prosocial behaviour (Van Doesum et al., 2017), we hope that the current findings will provide a neuroscientific base for future research to build on. In social cooperation, costs do not have to be high for prosocial decisions to be effective on an interpersonal level; as long as they are seen.

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Declaration of interest

None.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.neuropsychologia.2017.12.009.

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