

[Back to previous page](#)



document 1 of 1

The neural basis of the bystander effect -- The influence of group size on neural activity when witnessing an emergency

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Abstract

Naturalistic observation and experimental studies in humans and other primates show that observing an individual in need automatically triggers helping behavior. The aim of the present study is to clarify the neurofunctional basis of social influences on individual helping behavior. We investigate whether when participants witness an emergency, while performing an unrelated color-naming task in an fMRI scanner, the number of bystanders present at the emergency influences neural activity in regions related to action preparation. The results show a decrease in activity with the increase in group size in the left pre- and postcentral gyri and left medial frontal gyrus. In contrast, regions related to visual perception and attention show an increase in activity. These results demonstrate the neural mechanisms of social influence on automatic action preparation that is at the core of helping behavior when witnessing an emergency.

Full Text

Introduction

People are social animals and thrive by interacting with other people. We want company when in misery and we help others when in need, be it physically or by means of donating time or money. Spontaneous helping behavior is observed throughout the animal kingdom and occurs in the absence of explicit reward (Preston, 2013), as observed for example in children and young chimpanzees (Warneken and Tomasello, 2006; Warneken et al., 2007). Yet these familiar intuitions were challenged in the sixties by a well-known finding in social psychology that revealed a dark side of human interaction, the 'bystander effect'.

The bystander effect refers to the decrease in helping behavior of an onlooker when a person is in need and multiple bystanders witness the emergency (Darley and Latané, 1968; for a recent meta-analysis see Fischer et al., 2011). Several explanations of this effect have been suggested among which pluralistic ignorance, diffusion of responsibility, and evaluation apprehension are mentioned most frequently (Fischer et al., 2011). All of these reflect interpretations that appeal to high level cognitive notions and provide a top-down explanation for social behavior. While these interpretations undoubtedly shed some light on group influences on individual behavior, they do not directly point to an underlying single or composite neural mechanism.

In line with a bottom-up explanation of social phenomena and mechanisms rooted in cross-species similarities (de Waal and Ferrari, 2010), the perception-action model proposes that merely observing someone in need will trigger a cascade of somatic and autonomic responses that have motor and emotional behavioral consequences (Preston and de Waal, 2002). Observing and responding to distress of another individual can be seen as a basic evolutionarily conserved mechanism, shared with other animals (Preston, 2013), that point to a less cognition based or more unintentional, implicit, action based process. Thus, witnessing an emergency (e.g., a person fainting) results in preparation of automatic helping behavior, and consequently in activation of brain areas related to preparation for action and coupling between the situation and adaptive behavior. Indeed, recent research using a variety of behavioral and neurophysiological methods has shown that already static social emotional information (e.g., emotional scenes or expressions) influences activation in the primary motor cortex (Hajcak et al., 2007; Schutter et al., 2008), supplemental motor area, middle frontal gyrus and the cingulate gyrus (de Gelder et al., 2004) and that this can be explained as a preparation for action (Frijda, 1986; Lang, 1993). The next question is whether this automatically triggered preparation for action is already influenced by social context, i.e. group size.

In the present study we investigated the neurofunctional basis of group influences on individual helping behavior. We used videos depicting the scene of an emergency and we manipulated the presence and group size of other persons at the scene. To tap into the automatic, attention-independent processes underlying helping behavior, participants performed a color detection task that was unrelated to the stimulus conditions and did not require cognitive involvement, or recognition or understanding of the situation. We tested the hypothesis that an increase in group size will decrease activity in regions which lie at the core of automatic preparation for action in the observer. This result would provide evidence of the influence of social context on automatic helping behavior as measured by a reduction in activation in the areas related to action preparation.

Materials and methods

Participants

Seventeen healthy, right-handed volunteers, (three males) aged between 18 and 27 years participated in exchange for money. Participants reported no psychiatric or neurological history, normal or corrected-to-normal vision, and no current use of psychoactive medications, except for women taking oral contraceptives. Written informed consent was

obtained and participants were unaware of the aim of the study. The experiment was carried out in accordance with the standards established by the Declaration of Helsinki and approved by the local ethics committee.

Stimuli

A real life situation served as a starting point for creating short movie clips using local amateur actors. In each scenario the central character was a woman shown fainting and falling to the floor but the number of people passing by her differed. Group size consisted of none, one, two or four bystanders (by0, by1, by2, by4; see Fig. 1 A). The people passing by were instructed to simply walk by when the woman fainted without intervention, but were allowed to look at the person in need if they wanted to or did so spontaneously. The notion of bystander usually refers to the situation where a crowd watches an emergency situation involving an individual, but experimental studies investigating the bystander effect have used multiple techniques (see Fischer et al., 2011) ranging from physical (increase in group size) to virtual (Internet). Here our aim was to use a bystander situation that can occur in real life and allowed testing in the well-controlled environment of a MRI scanner. We therefore used dynamic stimuli from the viewpoint of a person looking across the street. See Supplemental video for examples of the stimuli used. As an illustration of the realism and the notion of automatic helping behavior, we report the following anecdote. During the recording of one scene a woman who was not part of the group of actors rushed onto the set in distress and offered help to the woman 'fainting'.

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In total six unique videos per scenario were shot. The raw footage was edited using Adobe After Effects CS5 (Adobe Systems Inc., San Jose, CA, USA) and grayscale movies (720x576pixels, 25frames/s, total duration of 3s) were created. Movies were slightly blurred to reduce availability of facial information. Furthermore, a selection of the movies with none, one, two, or four people passing by was inverted and reversed (Control). In addition, another control scenario was created in which the person fainting, without bystanders present, stood up again (Standing). In this scenario, half of the movies consisted of the actress standing up again, whereas the other half was due to lack of material reversed and slowed down footage of the last part of the falling sequence to create the illusion that the person was standing up again. Movies were mirrored and three colored dots (80ms for each dot) were added to each movie for task purposes (see below). The dots always appeared on the bodies of people in the scene.

Design and procedure

Subjects performed a color-naming task as used previously (see, Sinke et al., 2010; Pichon et al., 2012). This task is unrelated to the effect of interest. Participants were instructed to indicate if the three colored dots presented during the movie were of the same or different colors (see Fig. 1 B). To control for possible motor anticipation the response alternatives appeared randomly left or right of the fixation cross and participants were instructed to react after offset of the stimulus. Participants performed four practice trials on different stimuli, showing the actress standing and waiting, outside of the scanner. There are several advantages of using this task. It counteracts possible social desirable thoughts and ruminations. The participants remain naive to the goal of the experiment since they are instructed to perform a color-naming task and the content of the movie is never mentioned to them. Thus, it will prevent excessive contemplation, but still allow a full comprehension of the social situation. This is of importance, since we wanted to tap into the whole range of activation related to responding to an emergency and not only into higher order, cognitive processes. This task counteracts possible differences in attention and the use of cognitive resources during the course of the experiment, between subjects and conditions. It will also allow a more ecological approach, as the demands on the subjects are similar as outside the laboratory. Instead of active looking for possible emergency situations, humans are most of the time suddenly confronted with an emergency while they are engaged in something else.

A slow-event related design was used. Following presentation of the stimuli (3s), an answer screen (2s) and a fixation interval (9 or 11s) were presented. Each session consisted of 4 experimental functional runs. Each run consisted of 36 trials and a total of 144 trials were presented with 24 trials per condition (2 repetitions of each unique and mirrored video). For 9 participants an anatomical scan was performed after 2 runs, while the anatomical scan of the other seven subjects was obtained in a separate session in which they performed a different experiment (Huis in 't Veld and de Gelder, under review).

Stimuli were presented using Presentation Version 14.8 (www.neurobs.com), projected onto a screen located at the end of the scanner bore. Participants viewed the stimuli via a mirror mounted with an angle of $\pm 45^\circ$ to the head coil. Each movie started at a new scan volume, as the onset of the stimuli was synchronized to a trigger from the scanner.

Image acquisition

Data was acquired with a 3-Tesla head scanner (MAGNETOM Allegra, Siemens, Erlangen, Germany). Earplugs were used to attenuate scanner noise and padding was used to reduce head movements. Gradient-echo T2*-weighted transverse echo-planar images (EPI) with blood oxygenation level-dependent (BOLD) contrast were used for functional scans. Each volume contained 32 axial slices acquired in an ascending-interleaved manner (repetition time (TR)=2000ms, echo time (TE)=30ms, slice thickness = 3.5mm, no gap, flip angle (FA)=90°, field of view (FOV)=224x224mm², matrix size=64x64). We collected a total of 267 functional volumes for each subject as well as high-resolution T1-weighted anatomical images using parameters from the Alzheimer's Disease Neuroimaging Initiative (TR=2250ms, TE=2.6ms, slice thickness=1mm, no gap, FA=90°, FOV=256x256 mm², matrix size=256x256).

fMRI preprocessing and analysis

Image preprocessing was carried out using BrainVoyager QX version 2.6 (Brain Innovation, the Netherlands, www.brainvoyager.com). The first 2 volumes of each run were discarded to avoid T1 saturation effects. Preprocessing of functional data consisted of incremental linear trend removal, temporal high-pass filtering, a rigid-body algorithm to correct for small movements between scans and spatial smoothing with a 4mm Gaussian kernel. Functional and anatomical data were normalized into Talairach space.

To map the increase and decrease in percentage change of the BOLD signal with the increase in group size a parametric-coded single-subject fixed-effects general linear model (GLM) with control, standing and response screen as additional predictors was used (see Fig. 1 C). Next, at the group level a random-effects GLM was performed. In addition, we calculated the following contrasts using a dummy-coded GLM. The influence of visual complexity was determined with a control>(by1+by2+by4) contrast and the effect of witnessing an emergency was investigated with the by0>standing contrast. All analyses were restricted using a mask to exclude non-brain voxels.

The statistical threshold for single voxels was set at FDR<0.05 with a cluster threshold of 40. For several maps we calculated the corrected cluster-level threshold (Forman et al., 1995; Goebel et al., 2005). This method corrects for multiple cluster tests across space. First, a single voxel threshold of $p=0.005$ (uncorrected) was used for initial statistical maps. As it was our analysis of interest, we used a single voxel threshold of $p=0.05$ (uncorrected) to calculate the corrected cluster-level threshold for the parametric decrease in BOLD signal with the increase in group size. Next, a whole-brain correction criterion was calculated estimating a false-positive rate for each cluster taking into account the spatial smoothness of the map. This was established by means of Monte-Carlo simulation (5000 iterations) and the minimum cluster size threshold applied to the statistical maps corresponds to a cluster-level false-positive rate (α) of 5%. Cluster size is reported in number of anatomical voxels and the used statistical threshold is indicated for each analysis in the corresponding table. Statistical maps are displayed on the Colin 27 average brain.

Results

Data from one participant was discarded due to technical failure. Mean accuracy $\pm$ SD during the color-naming task was 96.53 ± 2.14 . Comparing the different conditions revealed no differences in performance (p 's > 0.09), indicating that task difficulty was not a factor in the fMRI analyses.

Decrease in brain activity with the increase in group size

The parametric analysis showed a decrease in activity with the increase in group size in the left medial frontal gyrus and the left postcentral gyrus extending to the precentral gyrus (see Fig. 2 A and Table 1).

Increase in brain activity with the increase in group size

The right superior occipital gyrus, right lingual gyrus, left cuneus, and left middle temporal gyrus showed a parametric increase in activity (see Fig. 2 B and Table 1). The control > bystander contrast revealed significant clusters in the fusiform gyrus, precuneus, cuneus and middle temporal gyrus of the right hemisphere (see Table 2). Importantly, these regions only overlap with regions showing an increase, but not a decrease, in activation with the increase in group size.

Brain activity related to witnessing an emergency

The right cuneus was more active when the person was shown fainting and falling down without bystanders compared to the same person standing up again without bystanders. In addition, the right fusiform gyrus, right inferior temporal gyrus and left middle temporal gyrus and right middle occipital gyrus were more active when the person was standing up instead of falling down (see Table 3).

Discussion

The present study investigated the influence of group size on neural activity during unintentional observation of an emergency. The left precentral and postcentral gyri and the left medial frontal gyrus showed a decrease in activity with the increase in group size. In contrast, regions involved in visual processing and attention showed an increase in activity with the increase in group size. We propose that these results support the conclusion that group size during an emergency already influences activity in brain regions sustaining preparation for action.

Action is at the core of survival of the individual and the group (Panksepp, 1998), and activity in motor regions, including the precentral gyrus, has been found to be mediated by social emotion information (de Gelder et al., 2004; Hajcak et al., 2007; Pichon et al., 2012; Schutter et al., 2008). The observed decrease in this area is in line with the proposed reduction in automatic action preparation with the increase in group size. This provides a new perspective on the negative influence of group size on helping behavior as observed in the bystander effect. Automatic mechanisms can underlie the processing, action tendencies and the behavioral consequences of social cues and these are already influenced by contextual information (Gawronski and Cesario, 2013). The selection of an action, i.e. the decision to help or not, and providing help itself, can be implicit in nature, unintentional, independent of cognitive deliberation, while still be context-dependent (Preston, 2013). Indeed, empathic responses seem to be stimulus-driven and independent of task instruction (Avenanti et al., 2006). Moreover, previous studies using the same color-detection task as used here support the conjecture of automatic action preparation in response to social emotional information regardless of attention (Pichon et al., 2012; Sinke et al., 2010). For example, observing someone threatening another individual triggered activation in the premotor area and putamen regardless of the focus of attention (Sinke et al., 2010).

In addition to the precentral gyrus, the postcentral gyrus corresponding to the somatosensory cortex, and the medial frontal gyrus showed a decrease in activation with the increase in group size. Besides its importance for proprioception, the somatosensory cortex was found to be activated during the encoding of actions for later enactment (Eschen et al., 2007). The somatosensory cortex, but also the medial frontal cortex, is activated during representations and regulation of emotional states of oneself and other people (Adolphs et al., 2000; Etkin et al., 2011; Pitcher et al., 2008). The medial frontal cortex has been characterized as the visceral motor cortex (Neefsey et al., 1993) and is connected to a large number of brain areas relevant for adaptive behavior such as the amygdala, hypothalamus and periaqueductal gray (Gabbott et al., 2005). Moreover, it is involved in sustaining the associations between events and corresponding adaptive responses (Euston et al., 2012; Alexander and Brown, 2011). Thus, the parametric decrease in this area may reflect implicit decoupling between the observation of the emergency and action preparation in view of the appropriate behavioral response (i.e. helping). Indeed, activity in the medial frontal cortex has been linked to daily helping behavior of both friends and strangers (Rameson et al., 2012).

While the present results suggest that group size has already an effect at the level of preparation for action, this does not mean that other processes could not also play a role. For example, it was recently shown that in-group membership increases confrontational intervention in a bystander situation (Slater et al., 2013). Alternatively, higher-order processes could interact with automatic processes by possibly down-regulating corresponding neural activity. Therefore, in the present research we wanted to tap into automatic processing by focusing the attention of the participant on an unrelated task, in order to keep cognitive resources and attention at a constant level between conditions and throughout the course of the experiment. This was successful as no effect of the increase in group size was found on performance during the color-naming task. It is therefore unlikely that cognitive processes could explain the present results. However, future research should manipulate task demands (e.g., difficulty, attention, instruction) to disentangle higher-order from automatic processes when witnessing an emergency.

One may argue that the activation in motor areas we find here relates to the motor response during the color-naming task. But this is unlikely in view of the fact that several measures were taken to rule out the possibility that this could explain or mediate part of the results. First, a delayed response was used (i.e. participants responded after offset of the stimulus) thereby increasing the possibility to disentangle task-related and stimulus-related activations. Second, the response alternatives appeared randomly on the left or right of the screen in order to prevent motor anticipatory activity. Third, the response screen was also taken into account in the regression model in order to control for motor-related confounds. It is therefore unlikely that the present results are task- and not stimulus-driven.

The increase in activation with the increase in group size was limited to visual regions. It is suggested that vision is always affective vision (Pessoa, 2012). For instance, emotionally arousing content increases activation in extrastriate areas (Lang et al., 1998). However, given the overlap between areas showing an increase in activity with the increase in group size and areas activated in the visual control contrast, it is likely that the former activation is due to the increase in visual complexity.

A recent meta-analysis suggests that the bilateral insular cortex and medial and anterior cingulate cortex are activated when witnessing another individual's suffering (Lamm et al., 2011). In the present study, we found that when witnessing an emergency without bystanders activation was limited to the right cuneus. We provide two explanations for this contrast with the existing literature. First, empathy consists of multiple different phenomena ranging from emotion contagion to sympathy to cognitive empathy (Deutsch and Madle, 1975; Preston and de Waal, 2002). The present study did not focus on deliberate observation of an individual's suffering but on the consequence of unintentional observation of an emergency. Using a color-naming task we might have canceled cognitive empathy and other higher-order forms of empathy and more tapped into reflexive preparation to help (Preston and de Waal, 2002). Thus, one would expect that if the participant is given more time to contemplate the event, activation would shift to brain regions important for higher order empathic processes. Another explanation might be the occurrence of a repetition effect. The initial perception to the emergency might result in a strong emotional reaction in the subject, but repetitive presentation might reduce this reaction and corresponding activation patterns. While in the present study this possible effect might be reduced given the implicit processing of the stimuli, it might still have affected emotional and empathic reactions and thus corresponding neural patterns.

In conclusion, our results provide insight in the neural mechanisms of the bystander effect and show that group size influences neural responses already at the level of preparation for action. Subsequently, this reduces the individual's spontaneous tendency to help. The present study illustrates how complex and well-described social phenomena such as the bystander effect can be investigated inside the laboratory and how this may lead to a better understanding of the underlying neural mechanisms of social behavior.

The following is the supplementary data related to this article.

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.neuroimage.2014.02.025>.

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Conflict of interest

None declared.

Table 1
Parametric effect of number of bystanders.
Talairach coordinates

	Hemisphere	x	y	z	t	p	Cluster size
Decrease in activity with the increase in group size							
Medial frontal gyrus	LH	-7			37	-9 4.94	0.000177 2998
Postcentral gyrus	LH	-43			-26	45 4.19	0.000783 3511
Increase in activity with the increase in group size							
Lingual gyrus	RH	14			-74	-6 9.93	0.000000 719
Superior occipital gyrus	RH	32			-74	24 7.22	0.000003 246
Cuneus	LH	-25			-80	24 6.60	0.000008 58
Middle temporal gyrus	LH	-46			-68	18 7.65	0.000001 166

Table 2
Control>bystander.
p<0.005, cluster size corrected.
Hemisphere Talairach coordinates t p Cluster size

		x	y	z			
Fusiform gyrus	RH		29	-47	-3 4.97	0.000169	583
Fusiform gyrus	RH		23	-65	-9 6.47	0.000011	709
Precuneus	RH		32	-65	30 5.34	0.000083	612
Cuneus	RH		2	-83	18 4.62	0.000330	1194
Middle temporal gyrus RH			38	-53	3 4.94	0.000179	401

Table 3
Falling versus standing.
p<0.005, cluster size corrected.
Hemisphere Talairach coordinates t p Cluster size

		x	y	z			
Falling>standing							
Cuneus	RH		-1	-95	18 6.14	0.000019	804

Standing>falling

Fusiform gyrus	RH	38	-35 -12 7.06	0.000004 2020
Inferior temporal gyrus	RH	44	-68 0 6.45	0.000011 2863
Middle occipital gyrus	RH	29	-83 3 4.67	0.000300 373
Middle temporal gyrus	LH	-46	-65 9 6.16	0.000018 4573

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