Does belief in free will influence biological motion perception?

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Abstract

Previous research suggests that belief in free will correlates positively with intention perception. However, whether belief in free will is also related to more basic social processes is unknown. Based on evidence that biological motion is an intention-carrier, we investigate if belief in free will and related two beliefs, namely belief in dualism and belief in determinism, are associated with biological motion perception. Signal Detection Theory (SDT) was used to measure participants' ability to detect biological motion from scrambled background noise (d') and their response bias (c) in doing so. In two experiments, we found that belief in determinism and belief in dualism, but not belief in free will, were associated with the perception of biological motion. However, no causal relationship was found when experimentally manipulating free will-related beliefs. In general, our research suggests that basic social processes, like biological motion perception, can be predicted by high-level beliefs.

Key words: high-level beliefs, social perception, biological motion, free will belief, determinism belief, dualism belief

Introduction

Abraham Lincoln once said: “To believe in the things you can see and touch is no belief at all, but to believe in the unseen is a triumph and a blessing.” From a daily life perspective, beliefs are mental constructs of which one cannot easily prove the existence but that still have a great influence on our personal life. Among those beliefs, religious or philosophical beliefs are often considered high-level beliefs (Hill & Whistler, 2013, p. 91-93). Common examples of such high-level beliefs are just-world beliefs (Lerner & Simmons, 1966), mind-body dualism beliefs (Nadelhoffer et al., 2014), and paranormal beliefs (Tobacyk, 2004). However, another extremely important class of beliefs are free will beliefs (Genschow et al., 2017).

The existence of free will has been a topic of debate throughout human history, both in academia and in daily life. In the beginning, this debate was mostly restricted to philosophy (Kane, 2011; Van Inwagen, 1983). More recently, however, also cognitive psychologists have entered the field by studying the unconscious determinants of volitional behavior. A key finding from this work is that preparatory brain activity occurs already a couple of hundred milliseconds or even seconds before participants are aware of their motor intention (Libet, 1985; Libet et al., 1993; Soon et al., 2008). These findings have often been used as an argument against free will and caused the idea that free will does not exist to spread throughout society (Brass et al., 2019). This is important, because research suggests that free will beliefs can influence social behavior, thoughts, and feelings as well as more fundamental processes of social cognition. For example, studies have shown that reducing individuals’ belief in free will triggers antisocial behavior, such as cheating (Martin et al., 2017), aggressiveness (Baumeister et al., 2009), and reduced feelings of gratitude (MacKenzie et al., 2014). According to a prominent view, this is because free will forms the basis for moral responsibility (Nahmias et al., 2007; Sarkissian et al., 2010). That is, if

free will does not exist, then we are not in control of our actions and cannot be held accountable. As a result, disbelief in free will reduces the motivation to control our urges, leading to more antisocial behavior (Lynn et al., 2013; Rigoni et al., 2012). Supporting this argument, research has found that disbelief in free will indeed reduces intentional control (Lynn et al., 2013; Rigoni et al., 2011). While some of this research has been difficult to replicate (Crone & Levy, 2019), and a recent meta-analysis questions down-stream effects of free-will belief manipulations (Genschow et al., 2020), correlational research seem to support the relationship of free will beliefs with social behavior (Feldman et al., 2016; Genschow et al., 2019; Mercier et al., 2020; Seto et al., 2020; Stillman et al., 2010).

But how does belief in free will affect social perception? If people believe they have no control over their own actions, do they then also perceive other people as less intentional? To address this question, Genschow and colleagues (Genschow et al., 2017) investigated whether belief in free will can reduce the fundamental attribution error: the tendency to attribute other people's behavior more to internal intentions than to situational influences (Gilbert & Malone, 1995). The results revealed that belief in free will was indeed negatively correlated with this bias and that experimentally reducing free will beliefs likewise reduced internal attributions. Similarly, in a study where participants had to evaluate the intentionality of soccer players committing ambiguous handballs, Genschow et al. (2019) found that participants' belief in free will correlated positively with perceived intentionality. In addition, a similar correlation was also found when asking participants to judge the intentionality of moving abstract geometrical shapes (Heider & Simmel, 1944; Genschow et al., 2019). In sum, these results suggest that belief in free will not only causes us to experience intentional control over our own actions but also to perceive intention in others.

A key question, however, is whether belief in free will is also related to more fundamental social processes. An important such process is biological motion processing. Throughout evolution, human beings have developed an ability to recognize and interpret the movements of biological agents (Rutherford & Kuhlmeier, 2013, p. 11-12). This, in turn, is essential for inferring the goals and intentions of other people and animals (Troje et al., 2013). Biological motion is often studied using point-light displays (Johansson, 1973, 1976), in which the main joints of the human body are represented as a constellation of dots. Research suggests that these moving point-light animations carry a wealth of socially meaningful information, such as age (Montepare & Zebrowitz-McArthur, 1988), gender (Cutting & Kozlowski, 1977), mood (Chouchourelou et al., 2006; Dittrich et al., 1996), and personality traits (Heberlein et al., 2004; Troje, 2008). Most importantly, point-light animations also provide intentionality cues (Hohmann et al., 2011; Sebanz & Shiffrar, 2009). For example, research has shown that observers can derive from point-light displays whether or not an actor lifting a box is trying to deceive others about the true weight of the box (Runeson & Frykholm, 1983).

Given that belief in free will has shown to be related to perceiving intentionality in others (Genschow et al., 2017) and that biological motion processing supports intentionality perception (Troje et al., 2013), we hypothesized that belief in free will would be related to biological motion perception. Specifically, we predicted that belief in free will, or related beliefs such as belief in determinism or belief in dualism (Wisniewski et al., 2019), would either make people more sensitive in detecting biological motion or more biased in seeing biological motion, even if there is none. To this end, we used Signal Detection Theory (SDT) to measure both participants' ability to detect biological motion in scrambled background noise (d') and their response bias in reporting biological motion. We then investigated the extent to which these measures were

influenced by belief in free will, determinism, and dualism. In Experiment 1, we first addressed these questions using a correlational approach. In Experiment 2, we then went one step further and experimentally manipulated belief in free will.

Experiment 1

Materials & Methods

Ethics Statement

Both experiments were conducted on Prolific (Palan & Schitter, 2018). Before starting the experiment, participants gave informed consent. All procedures were approved by the local ethics committee of the Faculty of Psychology and Educational Sciences at Ghent University.

Participants

We originally pre-registered the study at <https://aspredicted.org/ff5gr.pdf>. In this preregistration, we planned to use the average score of the Free Will Index (see below). However, before we ran the study, we discovered that the different subscales of this questionnaire are often not or inversely correlated. We therefore decided to update our preregistered analysis plan to use the separate subscales (<https://aspredicted.org/blind.php?x=r9qd28>). All participants included in the current study were tested after updating the preregistration. Participants performed two tasks, only one of which will be reported here. The sample size was based on a power analysis for the other task. That is, our goal was to obtain 80% power to detect an effect of the same size we had found in a previous study using that task ($r = 0.13$). The power analysis revealed that this required $N = 364$. However, as preregistered, we tested 420 participants to compensate for potential drop-out. After

removing participants who entered the experiment but did not complete it (e.g., no survey data), 405 valid participants were retained (198 women, 207 men). Participants were fluent in English, ranged in age from 18 to 40 ($M = 27.17$ years, $SD = 5.87$ years). Every participant recruited from the platform received at least £5/h for successful participation.

Stimuli, Task, and Procedure

The study consisted of two parts which involved two experimental tasks, created using the BMLkit (see <http://www.biomotionlab.ca/Experiments/>), and a series of questionnaires. First, participants were directed to an interface containing general information about the study. On the interface, participants saw an introductory text explaining the two following tasks. The first task (~ 5 minutes) was included in the context of another project and reaches beyond the scope this study. Here, we only report the results of the second task. In this task, participants had to decide on each trial whether they saw a point-light walker or not. Stimuli consisted of either a regular or scrambled point-light walker, combined with three types of scrambled background noise (43 dots vs. 61 dots vs. 88 dots), leading to 6 types of stimuli in total (see *Supplementary material*) (Thompson et al., 2008). Each walker consisted of 15 dots, corresponding to the main joints of the human body, and was rendered in white on a black background, using an orthographic camera with a horizontal optical axis. The orientation of the walker with respect to that axis was counterbalanced (-60° , -30° , 0° , 30° , or 60°) across trials in random order (see **Figure 1**) and the initial phase of the walking movement in each trial was randomized between 360° and 0° in increments of 30° . The scrambled walker was generated by scrambling the walker's dots along the x and y axes within the same area occupied by the intact walker. The scrambled mask was generated by randomly sampling dots from the walker and then placing them at random positions within the whole display area while retaining their local motion. Each stimulus was presented for

2s, followed by two response buttons prompting participants to indicate whether they had seen a walker or not. The response deadline was 4s and the inter-trial interval 0s. In total, each participant was presented with 180 trials.

Figure 1. Example of six orientations of walkers in this study. Note, that the lines connecting the dots are included only for illustrative purposes and were not shown in the actual experiment.

After completing this task, participants completed a series of questionnaires on LimeSurvey 3.15. Belief in free will was measured using the Free Will Inventory (FWI) (Nadelhoffer et al., 2014). The FWI measures three beliefs related to free will, namely belief in free will (FW), belief in determinism (DE) and belief in dualism (DU). The FWI consists of two parts. The first part contains 15 items and measures the strength of people's beliefs. The second part consists of 14 items and explores the relationships between the three measured beliefs. In the current experiment, participants only completed the first part of FWI, using a 7-points Likert scale ranging from 'Strongly disagree' to 'Strongly agree'. After completing the FWI, participants also completed the abbreviated internal-external locus of control scale (Valecha & Ostrom, 1974) and a series of questions asking participants to estimate the price of a variety of products. The locus of control scale was included because the concept of locus of control is closely related to that of belief in free will (Waldman et al., 1983). Hence, we included this scale

to rule out that our results were explained by locus of control rather than by free will beliefs. The pricing questions were included to pilot stimuli for a third project and will not be reported here.

Data Analysis

We excluded participants based on two criteria. First, we excluded participants who provided the same response on more than 90% of the trials. Second, we also excluded participants whose accuracy across the three different conditions was below chance level (i.e., 50%). In addition to these two preregistered exclusion criteria, we also applied two non-preregistered exclusion criteria. First, we excluded participants with excessive missing data. That is, because this was an online experiment, sometimes not all trials were saved on the server. While there was no ($N = 397$) or only limited ($N = 7$, $< 20\%$) missing data for most participants, a large number of trials ($\geq 95\%$) were missing for 1 participant. This one participant was excluded. Second, upon exploring the data, we noticed that there were a number of participants with an extreme response bias (see *Supplementary Figure S1*). Given that correlations are highly susceptible to such outliers, we therefore decided post-hoc to exclude response bias outliers using the Inter-Quartile Range (IQR) method ($N = 10$). After the above exclusions, 380 participants (183 women, 197 men, age ranges from 18 to 40, $M = 27.19$ years, $SD = 5.83$ years) were retained.

To test our hypothesis, as preregistered, we conducted two repeated measures ANOVAs: one with sensitivity as the dependent variable and one with response bias as the dependent variable. In both ANOVAs, we included the three noise levels as a within-subjects factor and free will beliefs as a covariate. This analysis was done separately for each of the three FWI subscales. We expected a relationship between free will related beliefs, especially the FW and DE subscales, and both dependent variables, possibly interacting with the level of noise.

Furthermore, we expected that these effects would still be present after controlling for locus of control by adding this variable as an additional covariate. All ANCOVAs were performed using the “afex” package in R (Singmann et al., 2015).

Sensitivity and response bias were calculated using “psycho” package in R (Makowski, 2018) by first sorting trials into four categories (hit, miss, correct rejection and false alarm) and then computing indices of sensitivity and response bias as proportions of these trials. Sensitivity (d') reflects the ability to detect biological motion from background noise and is calculated as the Z-value of the hit-rate minus that of the false alarm-rate ($d' = Z(P_H) - Z(P_{FA})$). While we initially planned to use β as a measure of response bias, we learned afterwards that this measure is not independent of d' (Stanislaw & Todorov, 1999). Therefore, we decided to replace it with the now more commonly used c measure. This measure reflects the tendency of responding “yes” or “no” to the stimuli and is calculated as the negative of the average of the z scores corresponding to the hit rate and the false alarm rate ($c = -(Z(P_H) + Z(P_{FA}))/2$). The more participants tend to respond ‘yes’ (i.e., a liberal response bias), the smaller the c value is. In contrast, the more participants tend to respond ‘no’ (i.e., a conservative response bias), the bigger the c value is. In our study, a more liberal bias reflects a higher tendency to report seeing the walker in the background noise.

Results

Descriptive statistics

Possible scores on the three subscales of the FWI range between 5 and 35. In the current sample, the mean scores of FW (*Cronbach's* $\alpha = .78$), DE (*Cronbach's* $\alpha = .75$) and DU

(Cronbach's $\alpha = .83$) of the FWI were 23.07 ($SD = 5.65$), 18.23 ($SD = 5.75$) and 22.32 ($SD = 6.89$), respectively. Possible scores on the abbreviated internal-external locus of control scale range between 11 and 44. In the current sample, the score was 28.00 ($SD = 5.87$, Cronbach's $\alpha = .70$).

Figure 2. Scatter plot of the relationships between the three FWI subscales and sensitivity in Experiment 1. **A.** indicates the scatter plot between Free Will belief and sensitivity. **B.** indicates the scatter plot between Determinism belief and sensitivity. **C.** indicates the scatter plot between Dualism belief and sensitivity.

Figure 3. Scatter plot of the relationships between the three FWI subscales and response bias in Experiment 1. **A.** indicates the scatter plot between Free Will belief and response bias. **B.** indicates the scatter plot between Determinism belief and response bias. **C.** indicates the scatter plot between Dualism belief and response bias.

Preregistered Analyses

The sensitivity (d') ANCOVAs indicated a main effect of background noise in all three models (i.e., with FW, DU, or DE as covariate), all $F(2, 756) \geq 17.40$, all $p < .001$, all partial $\eta^2 \geq .044$, showing that sensitivity decreased as background noise increased. In addition, there

were significant relationships between FW and sensitivity $F(1, 378) = 8.38, p = .004$, partial $\eta^2 = .022$, between DE and sensitivity $F(1, 378) = 5.06, p = .025$, partial $\eta^2 = .013$, and between DU and sensitivity, $F(1, 378) = 15.20, p < .001$, partial $\eta^2 = .039$ (see **Figure 2**). Importantly, these latter three effects remained present even after controlling for locus of control by adding this variable as an additional covariate (all $p \leq .025$).

The response bias (c) ANCOVAs likewise indicated a main effect of background noise in all three models, all $F(2, 756) \geq 20.03$, all $p < .001$, all partial $\eta^2 \geq .050$, indicating that participants became more conservative as noise increased. In addition, there was a significant negative relationship between DE and the response bias, $F(1, 378) = 5.18, p = .023$ partial $\eta^2 = .014$ (see **Figure 3**), indicating that the more people believe in determinism, the more liberal people will behave. Importantly, this latter effect remained present even when controlling for locus of control by adding this variable as an additional covariate ($p = .022$). The relationships between FW and the response bias, $F(1, 378) = 1.78, p = .183$, partial $\eta^2 = .005$ and between DU and the response bias, $F(1, 378) = 3.59, p = .059$, partial $\eta^2 = .009$, were not significant.

Exploratory Analyses

Our preregistered analysis indicated that FW, DU, and DE were all similarly related to d' , even though belief in determinism is often seen as the opposite of belief in free will (Kane, 2004). As the FWI does not contain reverse-coded items, part of these relationships could be the result of shared methods variance, such as an acquiescence bias (Baron-Epel et al., 2010). In a next step, we therefore conducted an exploratory analysis investigating the unique variance explained by each FWI subscale. To this end, we repeated the above analyses with all three subscales (i.e., FW, DE and DU) included simultaneously as covariates. The sensitivity analysis

indicated a significant negative relationship between FW and sensitivity, $F(1, 376) = 3.91, p = .049$, partial $\eta^2 = .010$, and between DU and sensitivity $F(1, 376) = 9.49, p = .002$, partial $\eta^2 = .025$, but no significant relationship between DE and sensitivity, $F(1, 376) = .061, p = .435$, partial $\eta^2 = .002$. The bias analysis indicated no significant negative relationship between FW and the response bias, $F(1, 376) = .39, p = .533$, partial $\eta^2 = .001$, between DE and the response bias, $F(1, 376) = 2.69, p = .102$, partial $\eta^2 = .007$, or between DU and the response bias, $F(1, 376) = 1.42, p = .234$, partial $\eta^2 = .004$. Together, this indicates that only dualism and free will beliefs reliably influenced sensitivity and that none of the three beliefs had a unique influence on the response bias.

Interim discussion

Previous research has shown that believing in free will is associated with increased intentional control and with increased attribution of intention to the behavior of others (Lynn et al., 2013; Rigoni et al., 2011). Here, we investigated whether belief in free will is also related to more fundamental social processes underlying intentional attribution, such as biological motion perception (Hohmann et al., 2011; Runeson & Frykholm, 1983; Sebanz & Shiffrar, 2009). Specifically, we hypothesized that belief in free will and to a lesser extent disbelief in determinism and belief in dualism would be associated with biological motion detection.

Separate analyses of belief in free will, belief in determinism, and belief in dualism showed that all three beliefs negatively predicted participants' sensitivity to biological motion. However, only belief in determinism predicted participants' response bias. Specifically, participants with higher beliefs in determinism were more inclined to report that there was

biological motion. A follow-up analysis including all scales together in the same model showed that only belief in dualism and belief in free will explained unique variance in perceptual sensitivity and that none of the three scales predicted response bias after accounting for the other scales. Overall, this suggests that the three scales might have shared variance and that after excluding this shared variance, only belief in dualism and belief in free will are related to participants' sensitivity in seeing biological motion.

Interestingly, these findings contradict with our original hypothesis of a positive correlation between especially belief in free will and biological motion detection. Given that our findings were unexpected, replication is warranted. Moreover, given that this was a correlational study, our results do not speak to the causality of the effects. Therefore, to confirm our findings and establish causality, we ran a second study, in which we experimentally manipulated belief in free will by means of anti-free will messages (Genschow et al., 2017) to see whether this influences biological motion detection. In line with Experiment 1, we predict that priming participants with a message that free will does not exist will result in lower sensitivity to detect biological motion compared with priming participants with a message unrelated to free will.

Experiment 2

Materials & Methods

Participants

We first pre-registered the study at <http://aspredicted.org/blind.php?x=4u4j87>. However, due to the extremely high exclusion rate after performing the preregistered manipulation check

on the initial 20 participants, we updated the preregistration with an adjusted manipulation check (see updated pre-registration: <https://aspredicted.org/blind.php?x=mx9tu5>). As before, the participants initially tested with the original preregistration were not included in the final sample. We planned to collect data from 350 participants. This sample size was based on a power analysis using the data from Experiment 1. In Experiment 1, effect sizes were relatively small, and transforming the correlations of belief in free will and belief in dualism with d' to Cohen's d indicated respective effect sizes of $d = 0.39$ and $d = 0.26$ ¹. Using the mean of these two values in a power analysis ($d = 0.33$) indicated that 300 participants were needed to obtain 80% power to detect an effect size for the manipulation similar in size to the correlational effects obtained in Experiment 1. However, we decided to collect 350 participants to compensate for potential drop-out. In addition, we also preregistered that we would add 50 more participants if the sample after exclusions dropped below 300 participants until our sampling goal of $N \geq 300$ was achieved. Eventually, 395 participants were included in this study (151 women, 240 men, 4 unknown). Participants were fluent in English and ranged in age from 18 to 40 ($M = 25.96$ years, $SD = 6.04$ years). Every participant recruited from the platform received at least 1.85£ for successful participation.

Stimuli, Task, and Procedure

The study consisted of four parts: a free will manipulation, the biological motion detection task, a secondary task, and a series of questionnaires. First, participants were directed

¹ A correlation of $r = 0.13$ was used for belief in free will in the power calculation but the actual correlation is $r = 0.15$. The difference is due to the fact that the initial correlation did not take into account all exclusion criteria.

to an interface containing information about the study and informed consent. On the interface, participants saw a basic introduction of the different tasks and clearly stated steps. Next, participants were randomly and equally assigned one of two groups. Half of the participants were assigned to the anti-free will group and the other half to the control group. All participants first read a text introducing Francis Crick and then a paragraph adopted from his book << *The Astonishing Hypothesis: The Scientific Search for the Soul* >> (Crick, 1994) (see Appendix A). Crucially, participants in the anti-free will group read a paragraph arguing that free will is an illusion and can be explained by neural activity, whereas participants in the control group read a paragraph about the general nature of consciousness (Genschow et al., 2017, 2019). After the free will manipulation, participants were asked to summarize the text in 2-3 sentences. In the next step, participants did the same biological motion task as in Experiment 1. After completing the biological motion task, participants did a second task, which was included for the purpose of another project and will not be discussed here. Finally, participants completed the Free Will Inventory, a manipulation check, and three questions regarding *COVID-19* that were included for exploratory purposes and will not be discussed here. The manipulation check was a multiple-choice question with 5 response alternatives asking about the main theme of the text they had read at the start of the experiment.

Data Analysis

We excluded participants based on three criteria. First, we excluded participants that provided the same response on more than 90% of the trials. Second, we excluded participants whose accuracy across the three different conditions was under 50%. Finally, we excluded participants who failed the free will manipulation attention check. That is, at the end of the experiment, participants were asked a question about the text they read at the beginning. We

excluded participants who did not answer correctly to the question or who spent less than 45s reading the text. In addition to these two preregistered exclusion criteria, we also added the same two non-preregistered exclusion criteria used in Experiment 1. That is, we also excluded participants with excessive missing data ($N = 0$, all participants had $\leq 21.11\%$ missing trials) and response bias outliers using the IQR method ($N = 6$). After applying these exclusions, 294 participants (121 women, 170 men, 3 unknown gender, age ranges from 18 to 40, $M = 26.18$ years, $SD = 5.97$ years) were retained², 139 in the anti-free will group (63 women, 73 men, 3 unknown gender, $M = 25.94$ years, $SD = 6.11$ years) and 155 in the control group (58 women, 97 men, $M = 26.39$ years, $SD = 5.84$ years).

As preregistered, we first tested whether the manipulation was effective with an independent samples t test on the mean value of the three subscales between the anti-free will group and the control group. Next, we tested the influence of the manipulation on biological motion processing using two 2 (manipulation) $\times$ 3 (background noise) mixed measures ANOVAs: one with d' and one with c as the dependent variable. Note that in line with Experiment 1, we initially planned to use β as a measure of response bias but later decided to use c upon learning that β is not independent of d' (Stanislaw & Todorov, 1999). We expected an influence of manipulation type on both dependent variables, possibly interacting with the level of noise. Third, to replicate the correlational findings of Experiment 1, we also conducted the same ANOVAs as above, but now with the three scales (free will, dualism, and determinism) added together as covariates. We expected an influence of the scales (especially dualism) on the dependent variables, possibly interacting with level of noise or the manipulation. Finally, as

² While we preregistered to add $N = 50$ participants when the sample after exclusions dropped below $N = 300$, we only decided on the last two exclusion criteria later (see Experiment 1 for rationale). Using only the preregistered criteria, the sample after exclusions was $N = 300$. Hence, we did not test additional participants.

preregistered, and in line with Experiment 1, we also repeated these ANCOVAs with each scale added separately to the model to assess these relationships without controlling for the other two subscales.

Results

Descriptive statistics

Possible scores on the three subscales of the FWI range between 5 and 35 in every group. For the anti-free will group, the mean score of FW (*Cronbach's* $\alpha = .85$), DE (*Cronbach's* $\alpha = .68$) and DU (*Cronbach's* $\alpha = .90$) were 20.99 ($SD = 6.19$), 17.24 ($SD = 5.28$) and 19.23 ($SD = 7.85$), respectively. For the control group, the mean score of the FW (*Cronbach's* $\alpha = .73$), DE (*Cronbach's* $\alpha = .72$), and DU (*Cronbach's* $\alpha = .83$) were 22.25 ($SD = 5.16$), 18.04 ($SD = 5.27$) and 21.41 ($SD = 6.45$), respectively.

Preregistered Analyses

Manipulation Check. The manipulation check revealed that scores on the DU subscale were significantly lower in the anti-free will group than in the control group, $t(267.87) = -2.59$, $p = .010$, *Cohen's* $d = -0.31$. There was no significant difference between the anti-free will and control group on the FW, $t(269.65) = -1.89$, $p = .059$, *Cohen's* $d = -0.22$, or DE subscales, $t(292) = -1.30$, $p = .194$, although the FW effect was close to significance.

Manipulation Effect on Sensitivity and Bias. The sensitivity (d') ANOVA indicated that sensitivity decreased as background noise increased, $F(2, 584) = 157.47$, $p < .001$, partial $\eta^2 = .350$. However, there was no effect of the manipulation, $F(1, 292) = .62$, $p = .432$, partial $\eta^2 = .002$, nor an interaction between the manipulation and noise level, $F(2, 584) = .80$, $p = .451$,

partial $\eta^2 = .003$. Similarly, the bias ANOVA indicated that participants became more conservative as background noise increased, $F(2, 584) = 167.05, p < .001$, partial $\eta^2 = .364$. However, there was no effect of the manipulation, $F(1, 292) = 1.51, p = .220$, partial $\eta^2 = .005$, nor an interaction between the manipulation and noise level, $F(2, 584) = .17, p = .848$, partial $\eta^2 < .001$.

Relationship between Free Will Beliefs and Sensitivity and Bias. To analyze the relationship between belief in free will and biological motion perception, we first added each scale separately to the above ANOVA. The sensitivity analysis revealed a significant relationship between DU and sensitivity (d'), $F(1, 292) = 5.35, p = .021$, partial $\eta^2 = .018$, but not between sensitivity and the other two scales, $F(1, 292) \leq 2.24, p \geq .135$, partial $\eta^2 \leq .008$ (see **Figure 5**). The response bias (c) analysis revealed a significant relationship between DE and bias $F(1, 292) = 4.39, p = .037$, partial $\eta^2 = .015$, but not between bias and the other two scales, $F(1, 292) \leq 2.66, p \geq .104$, partial $\eta^2 \leq .009$ (see **Figure 6**).

Adding the three subscales together as covariates to the sensitivity ANOVA revealed no significant relationship with either FW, $F(1, 289) = .03, p = .860$, partial $\eta^2 < .001$, DE, $F(1, 289) = 1.40, p = .238$, partial $\eta^2 = .005$, or DU, $F(1, 289) = 3.40, p = .066$, partial $\eta^2 = .012$, although the relationship with DU was close to significance. Adding the same three scales to the bias ANOVA revealed a significant negative relationship between DE and bias, $F(1, 289) = 3.97, p = .047$, partial $\eta^2 = .014$, but not between bias and the other two scales, $F(1, 289) \leq 1.88, p \geq .172$, partial $\eta^2 \leq .006$.

Figure 5. Scatter plot of the relationships between the three FWI subscales and sensitivity in Experiment 2. **A.** indicates the scatter plot between Free Will belief and sensitivity. **B.** indicates the scatter plot between Determinism belief and sensitivity. **C.** indicates the scatter plot between Dualism belief and sensitivity.

Figure 6. Scatter plot of the relationships between the three FWI subscales and response bias. **A.** indicates the scatter plot between Free Will belief and response bias. **B.** indicates the scatter plot between Determinism belief and response bias. **C.** indicates the scatter plot between Dualism belief and response bias.

Discussion

Experiment 2 followed up on the findings of Experiment 1 by testing whether free will related beliefs have a causal influence on biological motion detection. To this end, we manipulated belief in free will using an often-used scientific text (Crick, 1994). Although the manipulation check indicated that belief in dualism was significantly influenced by the scientific

text, we found no effect of our manipulation on either sensitivity or response bias. We did, however, find correlations between free will related beliefs and biological motion perception. First, with regard to perceptual sensitivity, we replicated the association with belief in dualism observed in Experiment 1 (although only when analyzing the scales separately). Second, with regard to bias, we found that belief in determinism predicted response bias. More specifically, Experiment 2 showed that the more participants believed in determinism, the more they tended to report seeing biological motion.

In sum, Experiment 2 found no causal effect of free will related beliefs on biological motion perception but did find similar relationships between these beliefs and the perception of biological motion as Experiment 1. However, while similar, the correlations were not entirely consistent across both experiments, with some effects reaching significance in one experiment but not in the other experiment and vice versa. To obtain a clearer picture, we therefore decided to conduct an additional exploratory analysis on the combined data of the two experiments ($N = 674$).

Figure 7. Scatter plot of the relationships between the three subscales and sensitivity across Experiments 1 and 2. **A.** indicates the scatter plot between Free Will belief and sensitivity. **B.** indicates the scatter plot between Determinism belief and sensitivity. **C.** indicates the scatter plot between Dualism belief and sensitivity.

Figure 8. Scatter plot of the relationships between the three FWI subscales and response bias across Experiments 1 and 2. **A.** indicates the scatter plot between Free Will belief and response bias. **B.** indicates the scatter plot between Determinism belief and response bias. **C.** indicates the scatter plot between Dualism belief and response bias.

Aggregate Analysis

The sensitivity (d') ANCOVAs indicated a main effect of background noise in all three models (i.e., with FW, DU, or DE as covariate), all $F(2, 1344) \geq 26.84$, all $p < .001$, all partial $\eta^2 \geq .038$, showing that sensitivity decreased as background noise increased. In addition, there were

significant relationships between FW and sensitivity $F(1, 672) = 9.09, p = .003$, partial $\eta^2 = .013$, between DE and sensitivity $F(1, 672) = 7.66, p = .006$, partial $\eta^2 = .011$, and between DU and sensitivity, $F(1, 672) = 21.26, p < .001$, partial $\eta^2 = .031$ (see **Figure 7**). The response bias (c) ANCOVAs likewise indicated a main effect of background noise in all three models, all $F(2, 1344) \geq 32.42$, all $p < .001$, all partial $\eta^2 \geq .046$, indicating that participants became more conservative as noise increased. In addition, there were significant relationships between DE and bias, $F(1, 672) = 9.87, p = .002$, partial $\eta^2 = .014$, between DU and bias, $F(1, 672) = 6.90, p = .009$, partial $\eta^2 = .010$, but not between FW and bias, $F(1, 672) = 2.68, p = .102$, partial $\eta^2 = .004$ (see **Figure 8**).

Including all three subscales (FW, DE, and DU) together as covariates revealed a significant negative relationship between DU and sensitivity, $F(1, 670) = 12.40, p < .001$, partial $\eta^2 = .018$, but no relationship between FW and sensitivity, $F(1, 670) = 2.55, p = .111$, partial $\eta^2 = .004$, or between DE and sensitivity, $F(1, 670) = 2.62, p = .106$, partial $\eta^2 = .004$. The same analysis on the response bias (c) revealed a significant negative relationship between DE and response bias, $F(1, 670) = 6.42, p = .012$, partial $\eta^2 = .009$, but not between DU and response bias, $F(1, 670) = 2.99, p = .084$, partial $\eta^2 = .004$, or between FW and response bias, $F(1, 670) = .042, p = .519$, partial $\eta^2 < .001$.

To summarize, the combined analysis confirmed that belief in dualism was associated with lower sensitivity in detecting biological motion, belief in determinism with a more liberal response bias, and belief in free will with neither. While these findings go against our initial hypothesis, one potential explanation for the unexpected negative relationship between belief in dualism and sensitivity could be that people who believe in dualism tend to perceive social stimuli as intentional even if they are not and that this then leads to reduced sensitivity

(Genschow et al., 2019). This is consistent with a previous study on the influence of paranormal beliefs on the perception of biological motion (Van Elk, 2013) showing that paranormal beliefs are inversely related to sensitivity and this can be explained by a positive relationship with false alarm rates. To test whether a similar mechanism could also explain the relationship we observed between dualism beliefs and sensitivity, we therefore ran a mediation analysis using the “mediation” package in R (Tingley et al., 2014). This indicated that, indeed, the influence of belief in dualism on perceptual sensitivity was fully mediated by the false alarm rate (see **Figure 9**).

Figure 9. Mediation analysis to determine whether $z(\text{FA})$ mediate the relationship between belief in dualism and sensitivity. Results indicate response bias as a significant full mediator influences the relationship between belief in dualism and perceptual sensitivity ($p < .001$).

General Discussion

Previous studies suggest that free will beliefs are related to the fundamental attribution error and to the perceived intention of social stimuli (Genschow et al., 2017, 2019; Lynn et al., 2013; Rigoni et al., 2011). However, no study so far has investigated whether free will beliefs are also related to basic social perception. Based on previous evidence that biological motion contains important cues about agent intentionality (Hohmann et al., 2011; Sebanz & Shiffrar,

2009), we hypothesized that free will beliefs would be related to the perception of biological motion. Specifically, we predicted that people who believe in free will would be better at perceiving biological motion.

Using a signal detection approach, our findings suggest that belief in free will as such does not predict perceptual sensitivity and response bias in detecting biological motion, which is contrary to our original hypothesis. However, when combining both experiments, we did find correlations with two beliefs related to belief in free will, namely belief in dualism and belief in determinism. Specifically, we found that sensitivity was predicted by belief in dualism and bias was predicted by belief in determinism, such that people who believed more strongly in dualism had lower sensitivity to biological motion and people who believed more strongly in indeterminism were more prone to report having seen biological motion. Together, this provides preliminary support for the hypothesis that high-level beliefs related to free will, like belief in determinism and belief in dualism, can predict low-level social processes such as biological motion processing. Given that biological motion processing plays an important role in evaluating intentionality (Hohmann et al., 2011; Runeson & Frykholm, 1983; Sebanz & Shiffrar, 2009), these findings potentially suggest that the previously observed relationships between free will related beliefs and intentional attribution (Genschow et al., 2019) arises already at the visual level.

However, it is important to note that even though we found relations with belief in dualism and belief in determinism, these were not in the direction initially predicted. With regard to dualism, previous research has shown that believing in the paranormal is associated with a reduced biological motion detection sensitivity, caused by a response bias to report seeing biological motion even when there is none (Van Elk, 2013). Given that we found a similar

negative relationship between dualism beliefs and biological motion detection sensitivity as those reported with paranormal beliefs (Van Elk, 2013), and given that previous work suggests that belief in dualism is strongly associated with paranormal beliefs (Willard & Norenzayan, 2013), this suggests that dualism beliefs were associated with reduced perceptual sensitivity because people who believe in dualism are more prone to see illusory patterns in noise. Indeed, in line with this hypothesis, a mediation analysis indicated that the influence of belief in dualism on perceptual sensitivity was fully mediated via false alarm rate.

The finding that increased belief in determinism was associated with a more liberal detection threshold, on the other hand, is more difficult to explain. One potential explanation might be that people who believe in determinism have a tendency to identify patterns in randomly moving dots. However, given that our mediation analysis indicated that this mechanism is likely to be at the basis of the dualism effects and given that belief in determinism and belief in dualism are typically seen as conflicting beliefs (Bear & Knobe, 2016; Nadelhoffer et al., 2014), this seems unlikely. Based on the observation that belief in determinism leads to reduced intentional control (Lynn et al., 2013; Rigoni et al., 2011), another explanation could therefore be that belief in determinism leads to a reduced response threshold and hence a more liberal response style. However, one should be aware of the post hoc nature of this line of reasoning.

Importantly, while our study indicates that free will related beliefs are associated with the perception of biological motion, we were unable to find a causal influence of these beliefs. While this might indicate that there is no causal relationship, it could also mean that the manipulation is not strong enough to have a downstream effect on biological motion perception. In this respect, it is important to note that the influence of the manipulation on free will beliefs, although reliable,

is rather weak (Genschow et al., 2017). Therefore, to definitively test whether there is a causal influence of belief in free will on biological motion detection, it will be important in future work to devise stronger manipulations that are more likely to trigger downstream effects.

Finally, a last point of discussion is whether the effects reported here are specific to biological motion or whether people who believe in dualism/determinism are simply more likely to see patterns in noise. Detecting the presence of other agents is a crucial skill for human beings to survive and reproduce. As stated by Barret (2004), human beings have evolved to be hyper-agency detectors. Such hyper-agency detection, in turn, has been argued to explain the human tendency to believe in the existence of invisible agents, such as spirits and angels, and in mind-body dualism (Bloom, 2005). These considerations suggest that the dualism associations reported here might be at least partly specific to biological motion detection. However, an important task for future research will be to investigate this more directly, for example, by investigating if pattern recognition in other contexts can explain the relationship between belief in dualism and the detection of biological motion.

Conclusion

In the current study, we wanted to investigate whether beliefs related to free will are associated with biological motion detection. In two experiments, we found that two beliefs related to free will, namely belief in determinism and belief in dualism, were associated with the perception of biological motion. However, no causal relationship was found when experimentally manipulating free will-related beliefs. Nevertheless, our research broadens the

perspective of top-down processing of social perception by demonstrating that free will related beliefs are related to low-level social perceptual processes and decision making.

Supplementary material

The demo animation of the stimuli (orientation is 0°) can be found here:
<https://www.dropbox.com/sh/9go5m3p4rzd7vpn/AABN04TF8x5Rkjswu40UKtA8a?dl=0>.

Figure S1. Scatter plot of a correlational relationships between three subscales and sensitivity. **A.**

indicates the scatter plot between Free Will belief and sensitivity. **B.** indicates the scatter plot between

Determinism belief and sensitivity. **C.** indicates the scatter plot between Dualism belief and sensitivity.

As can be seen, a small number of outliers with a very liberal response style have a large influence on the results

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