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8   Title: **Individual Differences in Social and Non-Social Cognitive Control**

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Abstract

Cognitive control refers to the ability of human beings to adapt flexibly and quickly to continuously changing environments. Several decades of research have identified a diverse range of mental processes that are associated with cognitive control but the extent to which shared systems underlie cognitive control in social and non-social contexts, as well as how these systems may vary across individuals, remains largely unexplored. By integrating methodological approaches from experimental and differential psychology, the current study is able to shine new light on the relationships between stable features of individuals, such as personality and sex, and the architecture of cognitive control systems using paradigms that index social (automatic imitation) and spatial processes. Across three large-sample experiments (>600 participants in total), we demonstrate that cognitive control systems are largely invariant to stable aspects of personality, but exhibit a sex difference, such that females show greater task-interference than males. Moreover, we further qualified this sex difference in two ways. First, we showed that the sex difference was unrelated to the sex of the interaction partner and therefore did not reflect an in-group bias based on sex. Second, we showed that the sex difference was tied to a form of spatial interference control rather than social (imitative) control and therefore it does not reflect a specialised mechanism for guiding social interactions exclusively. Instead, our findings suggest that a robust sex difference exists in the system (or set of subsystems) that operate in resolving a form of spatial interference control, and that such systems are unaffected by social factors such as the sex of the interaction partner. The results highlight the value of integrating approaches from experimental and differential psychology by providing a deeper understanding of the structure of cognitive control systems, whilst also providing new dimensions to incorporate into theories and models of social and non-social control.

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General Introduction

A remarkable feature of the human cognitive system is its ability to quickly and flexibly adapt behaviour to guide interactions with people and objects in the environment. The mental processes behind such adaptability are collectively referred to as cognitive control and have been the focus of growing research in cognitive psychology and cognitive neuroscience (Banich, 2009; O'Reilly et al., 2010; Botvinick & Cohen, 2014; Botvinick et al., 2001; Inzlicht, Bartholow, & Hirsch, 2015). To date, however, the extent to which shared systems underlie cognitive control in social and non-social contexts, as well as how these systems may vary across individuals, remains largely unexplored. As such, for a more complete understanding of the structure of social and non-social cognition, we need to investigate how general cognitive mechanisms operate across all individuals and contexts, as well as how different individuals vary from these general patterns (de Schotten & Shallice, 2017; Fischer-Baum et al., 2018). Thus, in the current paper, across three experiments, we integrate methodological approaches from experimental and differential psychology to investigate the extent to which cognitive systems relating to social (imitative) and non-social control differ between individuals, and whether such individual differences rely on domain-general or specialised control mechanisms.

Cognitive control is multi-faceted, with a core function being the ability to inhibit unwanted but dominant responses, in order to prioritise alternative, context-appropriate responses (Miyake et al., 2000; Payne, 2005; Chaiken & Trope, 1999). For example, non-social cognitive control may involve inhibiting automatic reading responses in a Stroop task (MacLeod, 1991), whereas social cognitive control may involve controlling automatic social biases based on race, sex or other social groupings

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69   (Amodio et al., 2004). The study of cognitive processes during social interactions has

70   received much attention in the last couple of decades across different methodologies

71   (Adolphs, 2009; Ochsner & Lieberman, 2001; Frith, 2008; Frith & Frith, 2012). For

72   example, researchers investigating social cognition have used methodologies from

73   cognitive psychology to provide experimental control over phenomena of interest to

74   social psychologists (Lambert & Scherer, 2013). One such example is that of

75   methodologies used to study automatic imitation.

76   Humans imitate a wide range of behaviours from their interaction partners,

77   including speech patterns, body postures, gestures and facial expressions (Brass et al.,

78   2000; Hansen et al., 2016; Bernieri, 1988; Dimberg, 1982; Webb, 1972). This behaviour

79   is usually not intended, often occurs without the conscious awareness of the imitator,

80   and is termed automatic imitation (Heyes, 2009; 2011). Automatic imitation has been

81   argued to function as a "social glue," powering cognitive and social development,

82   enhancing emotional reciprocity, and increasing feelings of affiliation, positive rapport

83   and pro-social behaviour (van Baaren et al., 2003; 2009; Lakin & Chartrand, 2003;

84   Chartrand & Bargh, 1999; Cacioppo et al., 2000; Kavanagh & Winkielman, 2016). Given

85   the substantial role automatic imitation plays in our social world, it has received

86   attention from diverse research disciplines. For instance, in social psychology, studies of

87   automatic imitation (termed motor mimicry) have typically involved measuring overt

88   copying behaviours during live social interactions (Chartrand & Bargh, 1999; Ray &

89   Heyes, 2011). In one such study, Chartrand & Bargh (1999) showed that even though it

90   was unrelated to the experimental task, participants copied a confederate's behaviour

91   such that they touched their face more than waggled their foot when the confederate

92   also touched their face, and vice versa.

By contrast, in cognitive psychology, stimulus-response compatibility (SRC) paradigms have been used in order to measure automatic imitation (Brass et al., 2000; Stürmer et al., 2000; Kilner et al., 2003). In a typical SRC task measuring automatic imitation, participants are required to lift their index or middle finger in response to a number cue ('1' for index finger, '2' for middle finger). Simultaneously, they see either the same finger movement (compatible condition) or a different finger movement (incompatible condition). Participants respond slower in the incompatible condition as the observed movement interferes with their response. This difference in reaction time between compatible and incompatible conditions is referred to as the compatibility effect and is considered to be a measure of automatic imitation control. The logic of the task is based on the idea that the observed action generates a motor representation of the same action in the observer. Thus, it has been suggested that on incompatible trials cognitive resources are required to inhibit the automatic tendency to copy an observed (incorrect) action and instead prioritise the alternative (correct) action (Brass & Heyes, 2005).

After establishing the basic SRC paradigm in order to measure a form of social (imitative) control, subsequent research on automatic imitation in cognitive psychology has provided insight into the factors that influence automatic imitation (Heyes, 2011; Cracco et al., 2018). These studies have typically used an experimental method, which measures the average influence of a manipulation across a group of participants, rather than a differential approach that measures differences across individuals. For example, previous research has found that factors like eye gaze and facial expressions of the interacting partner modulate the tendency to automatically imitate (Wang et al., 2011; Wang & Hamilton, 2014, Grerucci et al., 2013; Crescentini et al., 2011; Rauchbauer et al.,

117   2015, Butler et al., 2016). These findings suggest that social and contextual factors serve

118   as antecedents to automatic imitative behaviours.

119   Although a confluence of experimental and differential approaches has been

120   suggested as a step towards unification and to aid progress of psychological science as a

121   whole (Cronbach, 1975; Eysenck & Eysenck, 1985; Eysenck, 1997), these two streams of

122   thought have remained largely autonomous (Cronbach, 1957; Cramer et al., 2010). By

123   focussing on the experimental method, the contribution of individual differences tends

124   to be neglected (Eysenck, 1997). For example, in the context of social information

125   processing, a recent study found that tasks measuring mental state reasoning may

126   reflect socioeconomic characteristics of the sample as much as socio-cognitive

127   processes (Dodell-Feder et al., 2019). Thus, it is essential to embrace both experimental

128   and differential methods (including but not limited to sex, age, social class, culture, and

129   personality traits) in order to fully understand the complex underpinnings of social

130   interactions.

131   To aid cross-pollination between experimental and differential approaches,

132   more recent imitation research has started to take an individual differences approach

133   by investigating how characteristics of the imitator such as empathy, narcissism,

134   alexithymia and interoceptive awareness, influence automatic imitation (Chartrand &

135   Bargh, 1999; Hogeveen & Obhi, 2013; Obhi et al., 2013; Sowden et al., 2016; Ainley et al.,

136   2014). Such claims, however, are limited due to the small number of studies reported to

137   date, together with the use of relatively small sample sizes and a lack of powerful

138   replications. Moreover, further studies, which used considerably larger sample sizes,

139   have not been able to replicate the moderating influence of personality variables on

140   automatic imitation (Butler et al., 2015; Cracco et al., 2018). Interestingly, however,

141 Butler and colleagues (2015) showed that the sex of the participant modulated the

142 compatibility effect such that females showed a greater compatibility effect compared

143 to males. Therefore, it is possible that biological sex is a factor to consider further when

144 attempting to understand how cognitive mechanisms supporting imitation vary across

145 individuals.

146   Sex is an important individual difference that influences a wide range of

147 cognitive abilities and skills (Geary, 2010), as well as sensitivity to non-verbal social

148 cues (Hall, 1978). However, few studies have investigated how socio-cognitive abilities

149 vary as a function of biological sex and the ones that do have typically focused on

150 mental reasoning or emotion perception (Krach et al., 2009; Russel et al., 2007; Rahman

151 et al., 2004; Campbell et al., 2002). Further, such prior studies have often produced

152 mixed results based on relatively small sample sizes (Hyde, 2014; Miller & Halpern,

153 2014). Therefore, the potential influence of sex on complex cognitive mechanisms that

154 control non-verbal interactions, remains largely unknown.

155   The extent to which sex differences operate in imitative behaviour has also

156 received minimal attention to date. For example, no sex differences have been found on

157 the automatic imitation of actions or gestures (Chartrand & Bargh, 1999; Larsen et al.,

158 2010). By contrast, studies on facial mimicry have shown that females automatically

159 imitate facial expressions more than males (Dimberg, 1990; Sonnyby-Borgstrom et al.,

160 2008). Although there is no consistent empirical evidence to date, which speaks to sex

161 differences in imitation, there is theoretical reason to think that sex differences may

162 exist in imitative behaviour. Indeed, there is robust evidence for females to be more

163 empathetic than males (Christov-Moore et al., 2014; Baron-Cohen & Wheelwright,

164 2004). Further, empathy has been associated with a variety of paradigms investigating

165   imitation (Mueller et al., 2013; Sonnyby-Borgstrom 2002; Chartrand & Bargh, 1999).

166   Therefore, given that females are likely to be more empathetic than males in general,

167   this may lead to more imitative tendencies in particular social contexts.

168   A core question pertains to whether the sex difference seen in the SRC task is a

169   genuine difference between males and females or reflects an in-group/own-sex bias.

170   The stimuli used in the task by Butler and colleagues (2015) were of a female hand. It

171   may be that automatic imitation increases when the sex of the participant and the

172   interacting partner are matched. Group biases (typically in-group favouritism and out-

173   group dislike) are prevalent in day-to-day social interactions (Allport, 1954; Cameron et

174   al., 2001), relating to race, ethnicity (Ito & Bartholow, 2009; Kubota et al., 2012; Malpass

175   & Kravitz, 1969; van Bavel & Cunningham, 2009; Milner, 1983; Aboud 1988;), sex

176   (Brown, 1995; Yee & Brown, 1994; Fishbein, 1996, Powlishta, 1995; Rudman &

177   Goodwin, 2004), and arbitrary groups (Tajfel et al., 1971; Bernstein et al., 2007).

178   Therefore, ingroup biases seem like a powerful mechanism, which may guide imitative

179   behaviour based on the sex of the interaction partner.

180   In imitation research specifically, children have been known to imitate same-

181   sex models more than others (Shutts et al., 2010). Facial imitation and SRC measures of

182   automatic imitation have both been found to increase when the interacting partner is an

183   in-group member compared to an out-group member based on race, ethnicity and

184   arbitrary group assignment (Mondillon et al., 2007; Rauchbauer et al., 2015; Gleibs et

185   al., 2016). Moreover, recent work provides suggestive evidence for a sex difference

186   and/or in-group bias in the automatic imitation task (Cracco et al., 2018; Genschow et

187   al., 2017). For example, a meta-analysis found a higher reaction time compatibility

188   effect when the sex of the stimuli matched the sex of the majority of participants in the

189 sample (Cracco et al., 2018)[1]. However, the extent to which this sex difference reflects

190 an in-group bias remains unclear because no existing study has manipulated the sex of

191 the stimuli across male and female participants.

192   Two other possible explanations exist. First, the sex difference on the automatic

193 imitation SRC task could reflect that females tend to automatically imitate more than

194 males, and therefore require more cognitive resources to inhibit the tendency to

195 automatically imitate, leading to a greater compatibility effect. If so, the sex difference

196 would be tied to a process related to imitation specifically. Second, the sex difference

197 may be more domain-general in nature i.e. it may reflect a basic difference in the

198 cognitive systems that underlie performance on SRC tasks more generally. Consistent

199 with a domain-general explanation, sex differences have been found on many non-social

200 inhibitory control tasks which, like the imitation task, require the inhibition of task-

201 irrelevant automatic response tendencies in order to enforce a task-relevant response

202 (e.g. flanker, oddball, gaze- and arrow-cueing, and Simon tasks; Stoet, 2010; Judge &

203 Taylor, 2012; Clayson et al., 2011; Rubia et al., 2010; Bayliss et al., 2005; Merritt et al.,

204 2007; Alwall et al., 2010). As such, sex differences in SRC tasks may reflect differences in

205 cognitive systems that operate across these tasks such as selective attention (Clayson et

206 al., 2011) and/or spatial processing (Stoet, 2017).

207   These findings suggest that it is as yet unclear whether the sex difference on

208 SRC measures of automatic imitation reflect more domain-general processes or

209 processes solely tied to imitative control (Butler et al., 2015; Cracco et al., 2018;

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[1] However, the authors of the meta-analysis categorised a sample as "female" if more than half the population was female. Thus, even samples with 51% females would be classified as a female sample, biasing the interpretation of the consequent analysis and making clear conclusions difficult to reach.

210   Genschow et al., 2017; Darda et al., 2018; Darda & Ramsey, 2019). The SRC task used by

211   researchers to demonstrate the existence of a sex difference was a composite of both

212   spatial and imitative components (Butler et al., 2015; Genschow et al., 2017). A sex

213   difference solely tied to imitative control might suggest that a distinct mechanism, or a

214   partially distinct set of mechanisms, may underpin performance on the automatic

215   imitation task compared to other inhibitory control tasks. Thus, in order to understand

216   the cognitive architecture of social interactions, it is critical to unpack the relative

217   contributions of both general and specific components in socio-cognitive processes

218   (Michael & D'Ausilio, 2015; Spunt & Adolphs, 2017; Binney & Ramsey, in 2020; Ramsey,

219   2018; Ramsey & Ward, 2020). Therefore, in the current study, we investigate sex

220   differences on the automatic imitation task as well as a non-social control task in order

221   to investigate whether the sex difference relies on domain-general and/or domain-

222   specific mechanisms.

223   In the current paper, across three large-sample experiments, we integrate

224   approaches from experimental and differential psychology approaches to investigate

225   critical questions pertaining to individual differences in a form of social (imitative) and

226   non-social cognitive control. First, consistent with recent suggestions to make

227   replication a common and foundational practice in psychology (Zwaan et al., 2018), we

228   aim to confirm the sex difference found previously (on both social and non-social

229   cognitive control tasks) and provide a more precise estimate of the effect size. Further,

230   we aimed to replicate the lack of variation in automatic imitation as a function of

231   personality traits that has been reported previously in large sample research designs

232   (Butler et al., 2015; Cracco et al., 2018). Second, we aim to investigate whether the sex

233   difference on the imitation task reflects an actual difference between males and females,

234   or an in-group or own-sex bias. Third, we aim to uncover whether mechanisms

235 underlying the sex difference are domain-general or domain-specific (or a combination

236 of both).

<p style="text-align:center">Experiment 1</p>

237

238 **Introduction**

239   In the first experiment, we aim to replicate the sex difference on the general

240 compatibility effect found previously (Genschow et al., 2017; Butler et al., 2015). We

241 extend this research by investigating whether performance on a non-social inhibitory

242 control task (the flanker task) also varies between the sexes. A similar sex difference on

243 both tasks would indicate that the sex difference is supported by differences in a basic

244 domain-general control system that underpin performance across social and non-social

245 tasks. Alternatively, a sex difference on only one task would indicate at least partially

246 distinct mechanisms as a function of sex.

247   Further, we also investigate the extent to which stable dimensions of

248 personality influence the control of automatic imitation as measured on the SRC task.

249 Prior work has provided mixed evidence regarding this question. Some studies have

250 found a link between automatic imitation and empathy and narcissism - automatic

251 imitation was higher for individuals who scored high on the empathy scale, and lower

252 for those who scored higher on the narcissism scale. (Chartrand & Bargh, 1999; Obhi et

253 al., 2013; Hogeveen & Obhi, 2013). There are theoretical grounds to also posit a link

254 between automatic imitation and two of the Big Five personality factors. Agreeableness

255 and extraversion have been previously linked to empathy, altruism, and sociability

256 (Barrio et al., 2004; Ashton et al., 1998; McCrae & Costa, 1999), and are thus considered

257 as contributors to prosocial behaviour (Graziano & Eisenberg, 1997). Thus, individuals

258 who are more agreeable and more extraverted may be more prosocial and could thus

259   imitate their interacting partners more than others. In addition, although debated

260   (Southgate & Hamilton, 2008; Hamilton, 2013), imitation abilities have been argued to

261   vary in atypical populations including autism spectrum disorders and schizophrenia

262   (Oberman & Ramachandran, 2007; Thakkar et al., 2014; Williams et al., 2001),

263   indicating that a relationship may exist between autistic-like and schizotypal traits and

264   automatic imitation.

265   The largest datasets to date, however, show that performance on the SRC task is

266   invariant to stable personality variables (Butler et al., 2015; Cracco et al., 2018). One

267   concern with such null effects of personality is that they may reflect the impoverished

268   social context of the SRC task. That is, effects of interest may only operate in more

269   socially meaningful contexts. Therefore, in Experiment 1, we make the social context

270   more meaningful by including emotional facial expressions within our design and

271   investigate the extent to which automatic imitation continues to remain invariant as a

272   function of personality. We included five face images depicting five emotional

273   expressions (fearful, angry, happy, sad, neutral), and personality variables included

274   extraversion, agreeableness, autistic-like and schizotypal traits, narcissism (grandiose

275   and vulnerability narcissism), empathy (empathic concern and perspective taking), and

276   alexithymia (for detailed information about measures used, see supplementary

277   material). We included only the perspective taking and empathic concern subscales of

278   the empathy questionnaire as we had directional predictions about these subscales –

279   prior evidence suggests a positive link between perspective taking and imitation, as

280   well as empathic concern and imitation (Santiesteban et al., 2012; Chartrand & Bargh,

281   1999). Following Butler and colleagues (2015), although there is reason to expect pro-

282   social dimensions of personality to be related to increased imitation, based on prior

283   empirical evidence using the SRC task, we would expect imitation to be invariant to

284   stable dimensions of personality.

Method

286   Across all experiments, we report how the sample size was determined, all data

287   exclusions, and all measures in the study (Simmons et al., 2011; 2012). Following open

288   science initiatives, all raw data are available online for other researchers to pursue

289   alternative questions of interest. For all three experiments, data pre-processing,

290   statistical analyses, and data visualisations were performed using R (R Core Team,

291   2018), unless otherwise specified. All raw data and code used for analyses are available

292   online (https://osf.io/fsh9b/). For all following experiments, we report our primary

293   and secondary questions of interest in Table 1.

294

EXPERIMENT NO.	PRIMARY QUESTIONS	SECONDARY QUESTIONS
1	a) Is there a sex difference on the automatic imitation task when imitative and spatial effects are combined? b) Is there a sex difference on the flanker task?	a) Is automatic imitation invariant to stable traits of personality even when the context is more social? b) Are flanker and imitation task compatibility effects correlated with each other? c) Are there sex differences in how stable dimensions of personality predict automatic imitation?
2	a) Is there a sex difference on the automatic imitation task when the imitative component is orthogonal to the spatial component? b) Is there a sex difference on the flanker task?	a) Is automatic imitation invariant to individual differences in empathy and alexithymia? b) Are flanker and imitation task compatibility effects correlated with each other?

		c) Are there sex differences in how empathy and alexithymia predict automatic imitation?
3	a) Is there a sex difference and/or an in-group bias (based on sex) on the imitative compatibility effect? b) Is there a sex difference and/or an in-group bias (based on sex) on the spatial compatibility effect?	a) Is automatic imitation invariant to stable traits of personality when it is independent of spatial confounds? b) Are there sex differences in how stable dimensions of personality predict automatic imitation?

Table 1. Table 1 highlights primary and secondary questions of interest for experiments 1, 2, and 3 of this paper.

We determined the sample size for our experiments as follows. For experiment 1, we aimed to collect as many participants as possible over a two-day data collecting session. Therefore, the stopping rule was to terminate data collection after day 2 of data collection. For Experiments 2 and 3, in order to focus our design on the primary research question, which concerned sex differences, we set a minimum sample size of 100 male and 100 female participants. Sensitivity analyses revealed that given a sample size of two hundred participants (100 per sex), we would have 80% power to detect an effect size of Cohen's d > 0.35 for the mean difference between the two sexes on a one-tailed t-test, and an effect size of $\eta_p^2 > 0.04$ for a 2 x 2 mixed ANOVA. Such a design, therefore, provides reasonable confidence (80%) to detect effect sizes of interest that are conventionally considered small-to-medium.

Participants

311   Two hundred and three participants took part in this experiment for monetary

312   compensation (£6) or course credit. All participants provided informed consent, had

313   normal or corrected-to-normal vision, and were right-handed. Approval was obtained

314   from the Research Ethics and Governance Committee of the School of Psychology at

315   Bangor University. Participants were excluded if performance was three standard

316   deviations away from the group mean average performance per condition in terms of

317   accuracy or reaction time (N=14 for the imitation task, N=7 for the flanker task). A

318   further 14 participants were excluded as demographic information (sex of the

319   participant, or both age and sex of the participant) was not recorded. For the imitation

320   task, the final sample included 175 participants (59 males, $Mean_{age}$ = 20.9, SD_{age} = 4.23).

321   For the flanker task, the final sample included 182 participants (59 males, $Mean_{age}$ =

322   20.9, SD_{age} = 3.73).
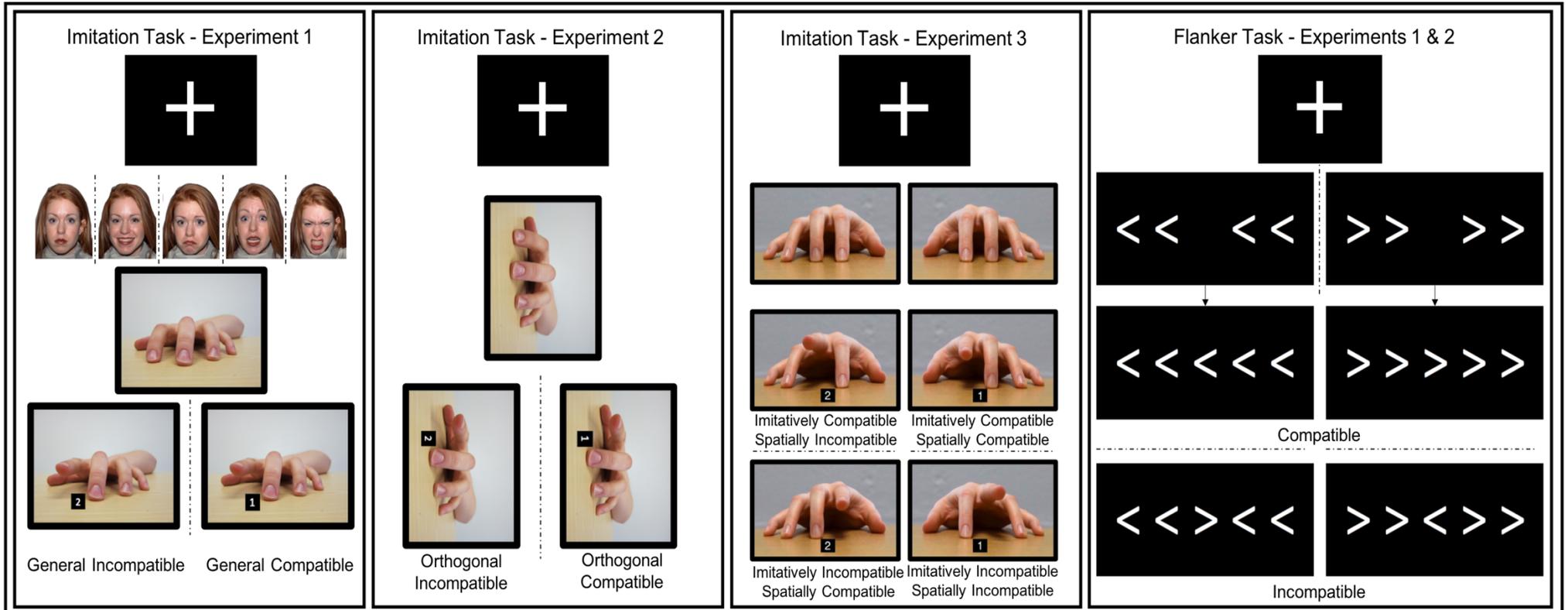
Figure 1. *Imitation and Flanker Tasks.* Stimuli and trial design for the imitation and flanker tasks in Experiments 1, 2, and 3. Flanker tasks were similar for

Experiment 1 and 2. In Experiment 1, in the imitation task, hand stimuli were preceded by a face depicting either a neutral, happy, sad, fearful, or angry image. In

Experiment 2, hand stimuli were presented orthogonal to the participant's response hand, and in Experiment 3, both left- and right-hand images were used in order

to measure imitative and spatial effects independent of each other.

330   *Stimuli, tasks, and procedure*

331   *Automatic imitation task.* The automatic imitation task was based on the stimulus

332   response compatibility (SRC) paradigm developed by Brass and colleagues (2000),

333   which consisted of the observation and execution of finger lifting movements (Figure 1).

334   In order to explore whether facial cues signalling emotional states influenced automatic

335   imitation, five face images depicting five different emotional states were also presented

336   along with the hand stimuli of the imitation task. The face stimuli were images of 5

337   female individuals from the NimStim data set with five different expressions (neutral,

338   sad, happy, fearful, and angry) (Tottenham et al., 2009). The hand stimuli comprised

339   five images of a female hand positioned in the centre of the screen and viewed from a

340   third person perspective such that the fingers extended towards the participants. The

341   first image was of the hand in a neutral position, while the remaining four images

342   showed either an index or middle finger lift with a number '1' or '2' presented between

343   the index and middle finger.

344   Participants were asked to hold down the "m" and "n" keys on the keyboard with

345   their index and middle fingers of the right hand, respectively. They were instructed to

346   lift their index finger when they saw a number "1" and their middle finger when they

347   saw the number "2". Thus, there were four possible trial types, two of which were

348   compatible, and two of which were incompatible. In the compatible condition,

349   participants were cued to perform the same finger-lifting movement that they observed

350   (i.e. an index finger movement with a '1' or a middle finger movement with a '2'). In the

351   incompatible condition, the executed and observed movements were different (i.e. an

352   index finger movement with a '2' or a middle finger movement with a '1').

353   Each trial began with the presentation of a fixation cross for 500 milliseconds

354   (ms). A face image was presented at the top of the screen after the fixation cross for 500

355   ms, followed by the neutral hand image in the centre of the screen. The face image

356   remained on the screen above the neutral hand and target hand image for the

357   remainder of the trial. The neutral hand was presented for a random inter-stimulus

358   interval (ISI) of 500, 700, or 1000 ms, followed by the target hand image. The

359   succession of neutral and target hand images was such that it produced apparent

360   motion of either an index or middle finger lift simultaneously with the presentation of

361   the number cue. The target hand image remained on the screen until the participant

362   made a response (but no longer than 2000 ms). The total trial length varied depending

363   on the ISI, but was never longer than 3500 ms. Trials were pseudo-randomised in such a

364   way that no more than 4 identical trials were presented consecutively. There were four

365   blocks of 50 trials each which included 25 compatible trials and 25 incompatible trials

366   with equal number of trials per face image.

367   *Flanker task.* The flanker task was based on the paradigm developed by Erikson

368   and Erikson (1974; Figure 1). The stimuli consisted of five equally sized and spaced

369   white arrows on a black background. Participants were instructed to respond to the

370   direction of the central arrow – they were asked to press key 'm' with their right index

371   finger if the central arrow pointed to the right, and press key 'n' with their left index

372   finger if the central arrow pointed to the left. The direction of the flanker arrows was

373   either compatible (<<<<< OR >>>>>) or incompatible (<<><< OR >><>>) to the central

374   arrow direction. This produced four trial types and two conditions (compatible and

375   incompatible).

376   Each trial started with a fixation cross for 800 ms, 1000 ms, or 1200 ms. The

377   flanker arrows then appeared on the screen for 100 ms, followed by the central arrow

378 in between the flankers. The five arrows remained on the screen until the participant

379 responded (but for no longer than 1600 ms). Participants were first presented with the

380 fixation cross for 800 ms, 1000 ms, or 1200 ms, followed by the presentation of the four

381 flanker arrows for 100 ms. Total trial length was never longer than 2900 ms. Trials

382 were pseudo-randomised in such a way that no more than 4 identical trials were

383 presented consecutively. Each participant did one block of 64 trials, with 32 compatible,

384 and 32 incompatible trials. Further, in this experiment, we addressed an additional

385 unrelated question – in half of the compatible and incompatible trials, flanker arrows

386 flipped arrow direction during the trial between their initial presentation on the screen

387 and the appearance of the central arrow. However, as we were interested in the basic

388 compatibility effect, we collapsed trials across conditions irrespective of whether they

389 changed direction mid trial or not.

390   Participants first completed the automatic imitation task, followed by the flanker

391 task. Before starting each task, they completed a 10-trial practice block.

392   *Questionnaires.* Participants also completed a range of self-report questionnaires

393 which included the Mini International Personality Item Pool (mini IPIP; Donnellan et al.,

394 2005; the Short Autism Spectrum Quotient (AQ-10 Adult; Baron-Cohen et al., 2001;

395 Allison et al., 2012), the Brief Schizotypal Personality Questionnaire (SPQ-B; Raine &

396 Benishay, 2005), the Narcissistic Personality Inventory (NPI-16; Ames et al., 2006), the

397 Hypersensitivity Narcissism Scale (HSNS; Hendin & Cheek, 1997), the Interpersonal

398 Reactivity Index (IRI; Davis, 1980), and the Toronto Alexithymia Scale (TAS-20; Bagby

399 et al., 1994). For more details on the measures used and how the questionnaires were

400 scored, see the Supplementary Material.

401 *Data Analysis*

402   Accuracy on the imitation task was recorded as the proportion of trials that were

403   correct i.e. when participants lifted the correct finger in response to the number cue.

404   Reaction time (RT) was recorded as time taken from target onset to participant's

405   response. Only correct trials were used to calculate RT. Trials on which participants

406   responded incorrectly, i.e. lifted the wrong finger, responded after 2000 ms, or before

407   target onset were all excluded from the analysis (5.64%).

408   Accuracy on the flanker task was recorded as the proportion of trials that were

409   correct i.e. when participants pressed the correct button in response to the central

410   arrow direction. RT was calculated as the time taken from target onset (i.e. presentation

411   of the arrow) to when the participant made a response. Only correct trials were used to

412   calculate RT. Trials on which participants responded incorrectly, i.e. lifted the wrong

413   finger, responded after 1600 ms, or before target onset were all excluded from the

414   analysis (4.77%). Compatibility effects were calculated for both the flanker and

415   imitation tasks by subtracting reaction times on compatible trials from reaction times

416   on incompatible trials.

417   Data was analysed as follows: first, for both the RT and accuracy data on the

418   imitation task, a 2 (compatibility: incompatible, compatible) x 5 (emotion: neutral, sad,

419   happy, fearful, angry) repeated measures ANOVA was performed to investigate whether

420   facial cues signalling emotional states modulated the compatibility effect on the

421   imitation task. Second, on both RT and accuracy data, for the flanker and imitation tasks

422   separately, a 2 (compatibility: compatible, incompatible) x 2 (sex: male, female) mixed

423   ANOVA was performed in order to investigate whether the compatibility effect on the

424   imitation and flanker tasks varies as a function of sex. For all ANOVAs, we report

425   Greenhouse Geisser corrected values if the assumption of sphericity is violated. Third,

426   in order to investigate whether the flanker and imitation compatibility effects were

427   correlated, a one-tailed Pearson's correlation was performed. A positive correlation

428   would suggest that the two compatibility effects were related to each other.

429   Based on prior research (Heyes, 2011; Brass et al., 2000; Eriksen & Eriksen,

430   1974), we expected a main effect of compatibility on the 2 x 2 ANOVA such that RT

431   would be higher, and accuracy would be lower on incompatible trials compared to

432   compatible trials. In support of our hypothesis, we also expected a Compatibility*Sex

433   interaction such that the compatibility effect would be higher for females as compared

434   to males. The interaction effect was central to testing our primary hypothesis, and thus,

435   we calculated compatibility effects for male and female participants separately by

436   computing the mean difference and 95% confidence intervals between compatible and

437   incompatible conditions. In order to directly estimate the size of the difference in

438   compatibility effects between males and females, we then again computed the mean

439   difference and 95% confidence interval. We used one-tailed 95% confidence intervals

440   as we had a directional hypothesis that females would have a higher compatibility effect

441   than males on both the imitation and flanker tasks (Butler et al., 2015; Stoet, 2011;

442   Clayson et al., 2011). Further, we plot the group-average data and individual participant

443   data in the results section to ensure that any effects that go in a direction contrary to

444   our hypothesis can be visualised. We also provide all raw data online so that

445   researchers can test for alternative hypotheses.

446   We also report standardised effect sizes for ANOVA using partial eta-squared (η)

447   for independent samples t-tests using Cohen's d and for paired samples t-tests using

448   Cohen's d_z (Cohen, 1992; Lakens, 2013). We also report and interpret the point and

449   interval estimate using 95% CIs for effect sizes of interest in line with recent

450   suggestions (Cumming, 2012; Amrhein et al., 2019). In order to quantify the evidence

451   for a null hypothesis over the experimental hypothesis (where a null result was found

452   using null hypothesis significance testing; NHST), we calculated the Bayes factor (BF_{01})

453   by performing a Bayesian independent samples t-test to investigate the sex difference

454   between the sexes. We used default priors in JASP for the independent samples t-test,

455   that is, a Cauchy distribution3 with spread r set to $1/\sqrt{2}$. The Bayes factor was

456   interpreted using benchmark criteria from Jeffereys (1961). Bayesian analyses, Cohen's

457   d and d_z, as well as 95% CIs were calculated using JASP (JASP Team, 2018).

458   Further, as previous research demonstrated that the compatibility effect (as

459   measured on the SRC imitation task) is invariant to stable traits of personality (Butler et

460   al., 2015), we also investigated whether personality variables influenced automatic

461   imitation by using multiple regression analyses. We introduced a more social context to

462   the task by introducing facial cues signalling emotional expressions simultaneously with

463   the hand images. Based on prior work, we predicted that facial cues signalling positive

464   emotions would increase automatic imitation compared to neutral and negative

465   emotional expressions (Rauchbauer et al., 2015; Butler et al., 2016). Following Butler

466   and colleagues (2015), participant sex was coded as -1 for males and +1 for females.

467   Raw scores on all questionnaires and mean reaction time were centred i.e. the group

468   mean of a variable was subtracted from each individual score on that variable. We set

469   up a base model comprising mean RT (collapsed across all conditions), participant sex,

470   and the mean RT * sex interaction, as these factors have been shown to explain variance

471   in automatic imitation previously (Butler et al., 2015). We then individually tested the

472   contribution of each of the personality measures by adding them to the base model in

473   separate hierarchical multiple regression analyses. By doing so, we are able to address

474   the extent to which personality measures predict variance in the SRC imitation task

475   above and beyond the base model. To transparently visualise and report the data, we

476   also include zero-order correlations between personality measures and performance on

477 the SRC imitation task. As sex differences have been previously found on personality

478 measures (Schmitt et al., 2008), we computed sex*trait interaction terms for all

479 personality variables, and evaluated them in separate multiple regression models.

480 For all questionnaires used, we report reliability information as indexed by

481 Cronbach's alpha (Cronbach, 1951). For the imitation and flanker task compatibility

482 effects, we report the internal consistency of the measure by calculating split-half

483 reliability using a permutation-based split-half approach with 5000 random splits

484 (Parsons, 2018) using the splithalf package in R. All reliability analyses are reported in

485 the Supplementary Material.

486 Throughout the paper, following Gigerenzer (2018), we avoid interpreting

487 results based solely on p values and a binary distinction between "significant" and "non-

488 significant". Instead, we base the direction and strength of our interpretation on a range

489 of metrics, which include a p value and an associated measure of sensitivity (power),

490 effect sizes in original and standardised units along with a measure of precision using

491 95% confidence intervals (Cumming, 2012). Further, we run multiple replication and

492 extension experiments (Zwaan et al., 2018) and we meta-analyse the main effects

493 across experiments (Cumming, 2012), both of which help to further aid the confidence

494 that we can have in our findings and the credibility of the conclusions more generally.

495 **Results**

496 *Automatic imitation task*

497 *Accuracy.* Average accuracy on the imitation task was above 90% for both males and

498 females on both compatible and incompatible conditions (Supplementary Figure 1,

499 Supplementary Table 1). A 2 (compatibility: compatible, incompatible) x 5 (emotion:

500 neutral, sad, happy, fearful, angry) ANOVA showed no main effect of emotion ($F_{(4, 696)}$

501 $= 0.50$, p=0.729, $\eta_p^2 = 0.003$) and no Compatibility*Emotion interaction (F (4, 656) =

502 1.20, p=0.31, $\eta_p^2 = 0.007$). Thus, for all further analyses of accuracy, trials are collapsed

503 across all emotion conditions.

504 **Table 2.**

A) Experiment 1	Compatibility effect for the imitation and flanker task			
	Mean Difference (ms)	95% CI	Cohen's d_z/d	BF_{01}
Imitation task (General Compatibility Effect)				
Males	84.03	(75.19, ∞)	2.07 [1.68, ∞]	
Females	96.43	(89.49, ∞)	2.14 [1.86, ∞]	
Females - Males	12.40	(0.87, ∞)	0.28 [0.02, ∞]	
Flanker Task (Flanker Compatibility Effect)				
Males	51.17	(42.46, ∞)	1.28 [0.98, ∞]	
Females	56.79	(51.42, ∞)	1.58 [1.36, ∞]	
Females - Males	5.62	(-4.14, ∞)	0.15 [-0.11, ∞]	3.85
B) Experiment 2	Compatibility effect for the imitation and flanker task			
	Mean Difference (ms)	95% CI	Cohen's d_z/d	BF_{01}
Imitation task (Orthogonal Compatibility Effect)				
Males	25.79	(21.72, ∞)	1.02 [0.82, ∞]	
Females	32.77	(28.82, ∞)	1.28 [1.07, ∞]	
Females - Males	6.98	(1.34, ∞)	0.27 [0.05, ∞]	
Flanker Task (Flanker Compatibility Effect)				
Males	93.88	88.89	3.11 [2.71, ∞]	
Females	94.87	89.96	2.98 [2.62, ∞]	
Females - Males	0.98	(-6.01, ∞)	0.03 [-0.19, ∞]	6.58
C) Experiment 3	Spatial and imitative compatibility effects (collapsed across all levels of stimulus sex)			
	Mean Difference (ms)	95% CI	Cohen's d_z/d	BF_{01}
Spatial Compatibility (Spatially Incompatible – Spatially Compatible)				
Males	30.74	(27.64, ∞)	1.18 [1.02, ∞]	
Females	37.28	(33.97, ∞)	1.37 [1.20, ∞]	
Females - Males	6.53	(2.02, ∞)	0.24 [0.07, ∞]	
Imitative Compatibility (Imitatively Incompatible – Imitatively Compatible)				
Males	7.02	(4.50, ∞)	0.33 [0.21. ∞]	

Females	8.35	(5.95, ∞)	0.42 [0.30, ∞]	
Females - Males	1.33	(-2.15, ∞)	0.06 [-0.10, ∞]	4.95

Compatibility effects for the imitation and flanker tasks across Experiments 1, 2, and 3.

N.B. Compatibility effects for males and females, as well as the difference between males and females, for the imitation and flanker tasks are reported for Experiments 1, 2, and 3, along with 95% CIs, effect sizes and BF_{01}. Abbreviations: ms = milliseconds, CI = confidence intervals, BF = Bayes Factor.

The 2 (compatibility: compatible, incompatible) x 2 (sex: male, female) mixed ANOVA showed a main effect of compatibility such that participants were more accurate on compatible trials than incompatible trials ($F(1, 173) = 258.09$, p<.001, $\eta_p^2 = 0.60$; Supplementary Figure 1). The effect size for the main effect of compatibility is conventionally considered to be large. For the main effect of sex ($F(1, 173) = 0.22$, p = 0.64, $\eta_p^2 = 0.001$) and the Compatibility*Sex interaction ($F(1, 173) = 0.60$, p = 0.44, $\eta_p^2 = 0.003$), the effect sizes were close to zero (Supplementary Table 2).

Reaction time. Average reaction times on the imitation task for both males and females on both compatible and incompatible conditions were between 485 and 585 milliseconds (Figure 2, Supplementary Table 1). A 2 (compatibility: compatible, incompatible) x 5 (emotion: neutral, sad, happy, fearful, angry) ANOVA showed no main effect of emotion ($F (4, 696) = 1.81$, p=0.127, $\eta_p^2 = 0.004$). Importantly, the effect size for the Compatibility*Emotion interaction was close to zero ($F (4, 696) = 0.40$, p=0.796, $\eta_p^2 = 0.002$, see Supplementary Figure 2). Thus, for all further analyses of RT, trials are collapsed across all emotion conditions.

The 2 (compatibility: compatible, incompatible) x 2 (sex: male, female) mixed ANOVA showed a main effect of compatibility such that participants were slower to

530   respond on incompatible trials than compatible trials ($F(1, 173) = 669.77$, $p<.001$, $\eta_p^2 =$

531   0.80; Figure 2). The effect size for the main effect of compatibility is conventionally

532   considered to be large. Effect size for the main effect of sex was close to zero with a p-

533   value of p=0.61 ($F(1, 173) = 0.26$, $p = 0.61$, $\eta_p^2 = 0.001$). The Compatibility*Sex

534   interaction had a small effect size ($F(1, 173) = 3.16$, $p = 0.08$, $\eta_p^2 = 0.018$; Supplementary

535   Table 2).

536   To further explore our primary research question regarding sex differences in

537   the imitation task, compatibility effects were computed separately for males and

538   females, and then compared to each other. For both males and females, compatibility

539   effects had a large standardised effect size (Cohen's $d_z > 2.07$) with the lower bound of

540   the 95% confidence interval at 1.68 or higher. When compatibility effects for males and

541   females were directly compared to each other, we found a mean difference in the

542   direction that was predicted (females > males). Indeed, the compatibility effect for

543   females was 12.40ms higher than males and the lower bound of the 95% confidence

544   interval was 0.87ms (Mean Difference = 12.40 ms, 95% CI[0.87, ∞], Cohen's d = 0.28;

545   Figure 2, Table 2A). The standardised effect of d = 0.28 is conventionally considered a

546   small-to-medium effect, and the lower bound of the 95% confidence interval for the

547   effect size was just above zero (95% CI [0.02, ∞]). Thus, these findings suggest that

548   performance on the imitation task differs as a function of sex in a manner that is

549   consistent with our predictions, such that females had a greater compatibility effect

550   than males.
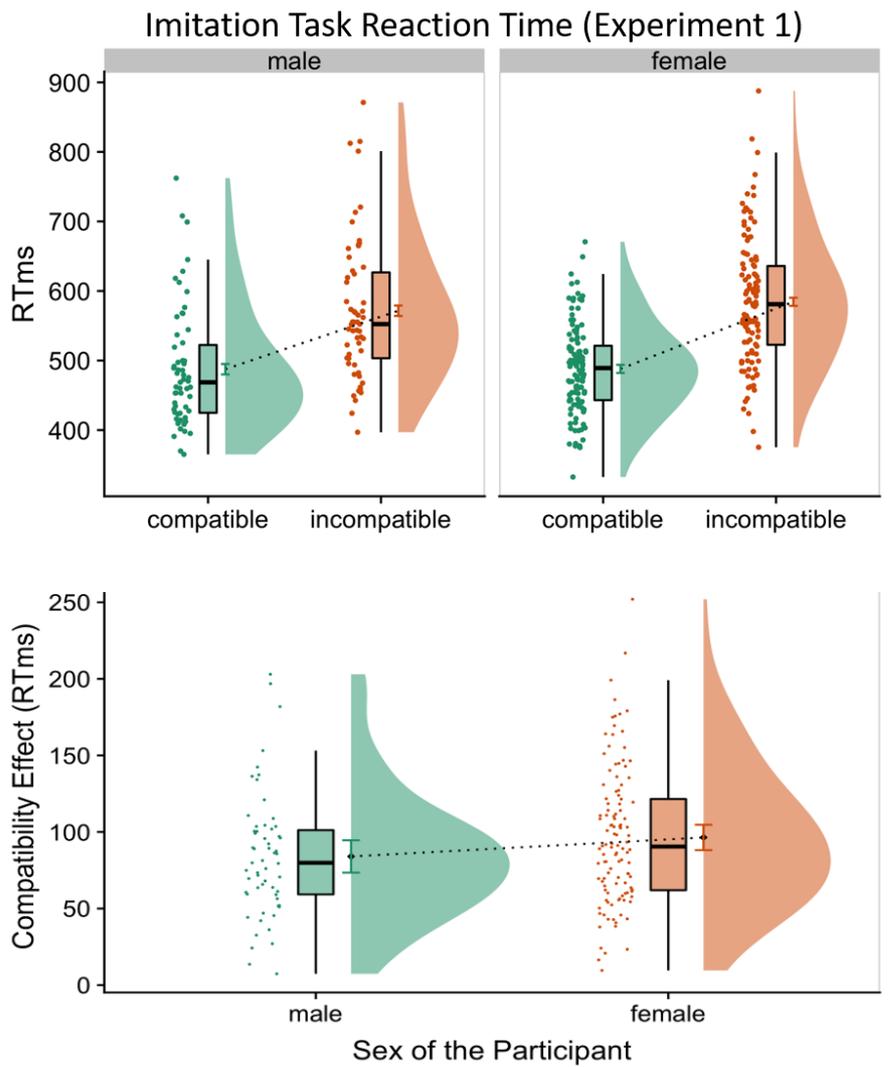
Figure 2. *Experiment 1 – Imitation Task Reaction Time.* Reaction time is reported in milliseconds (ms). The upper panel shows mean reaction times for compatible and incompatible conditions for both males and females. The lower panel shows the compatibility effect for both males and females. The compatibility effect is calculated by subtracting reaction times on compatible trials from incompatible trials. Error bars represent 95% confidence intervals. Abbreviations: RTms = reaction time in milliseconds.

Flanker task

Accuracy. Average accuracy on the flanker task was above 94% for both males and females on both compatible and incompatible conditions (Supplementary Figure 3, Supplementary Table 1). A 2 (compatibility: compatible, incompatible) x 2 (sex: male, female) mixed ANOVA was performed. The effect size for the main effect of compatibility was close to zero ($F(1, 180) = 2.24$, $p = 0.136$, $\eta_p^2 = 0.01$). Effect sizes for the main effect of sex and ($F(1, 180) = 0.04$, $p = 0.85$, $\eta_p^2 = <0.001$) and the

566   Compatibility*Sex interaction (F(1, 180) = 0.09, p = 0.759, η_p^2 < 0.001) were also close to

567   zero with p-values > 0.1 (Supplementary Table 2).

568   *Reaction time.* Mean reaction time on the flanker task for both males and females

569   on both compatible and incompatible conditions was between 420 and 495

570   milliseconds (Figure 3, Supplementary Table 1). A 2 (compatibility: compatible,

571   incompatible) x 2 (sex: male, female) mixed ANOVA (Figure 3) showed a main effect of

572   compatibility such that participants were slower to respond on incompatible trials than

573   compatible trials (F(1, 180) = 334.15, p<.001, η_p^2 = 0.65). The effect size for the main

574   effect of compatibility is conventionally considered to be large. The main effect of sex

575   had a small effect size and showed that overall females were slower than males on the

576   flanker task (F(1, 180) = 3.40, p = 0.08, η_p^2 = 0.02). The Compatibility*Sex interaction

577   had an effect size close to zero with a p-value of 0.34 (F(1, 180) = 0.90, p = 0.34, η_p^2 =

578   0.005; see Supplementary Table 2).

579   To further compare with the automatic imitation task, compatibility effects in the

580   flanker task were computed separately for males and females, and then compared to

581   each other. For both males and females, compatibility effects had a large effect size

582   (Cohen's d_z > 1.2) with the lower bound of the 95% confidence interval at 0.98 or

583   higher. When compatibility effects for males and females were directly compared to

584   each other, there was a trend toward females showing a higher compatibility effect than

585   males by 5.62ms, with the lower bound of the 95% confidence interval at -4.14 ms

586   below zero (Mean Difference = 5.62 ms, 95% CI[-4.14, ∞], Cohen's d = 0.15, 95% CI [-

587   0.11]; see Figure 3, Table 2A).The effect size was small, with the lower bound of the

588   95% confidence interval at -0.11. Thus, a reasonable estimate for the mean difference

589   between males and females on the flanker compatibility effect ranges from -4.14ms to

590   5.62 ms, with one possibility being a small difference between females and males, such

591   that females may show a higher compatibility effect than males. However, a Bayesian

592   independent samples t-test showed that the data was 3 to 4 times more likely under the

593   null hypothesis than the alternative hypothesis ($BF_{01} = 3.85$).
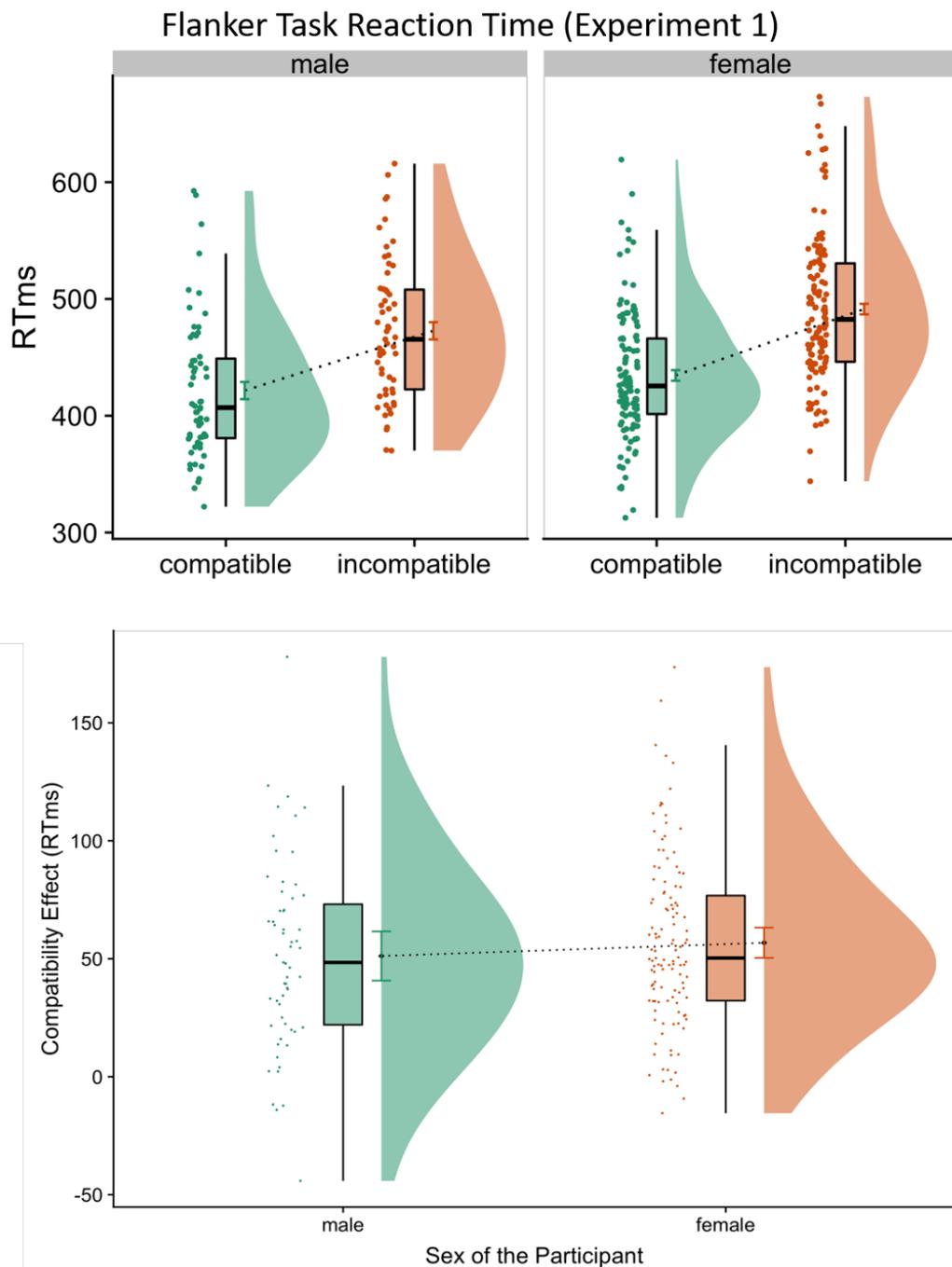
594
595   **Figure 3.** *Experiment 1 – Flanker Task Reaction Time.* Reaction time is reported in milliseconds
596   (ms). The upper panel shows mean reaction times for compatible and incompatible conditions
597   for both males and females. The lower panel shows the compatibility effect for both males and
598   females. The compatibility effect is calculated by subtracting reaction times on compatible trials

599 from incompatible trials. Error bars represent 95% confidence intervals. Abbreviations: RTms =
600 reaction time in milliseconds.

601

602 *Correlational analysis*

603 In order to investigate whether the flanker and imitation compatibility effects

604 were correlated, a one-tailed skipped correlation was performed. To do so, only those

605 participants who performed both the tasks were included in the analysis (N=165). The

606 skipped correlation analyses were performed using a Matlab-based toolbox

607 (Mathworks Inc., MA; http://sourceforge.net/projects/robustcorrtool/, Pernet, Wilcox,

608 & Rousselet, 2013). Skipped correlation takes into consideration the overall structure of

609 the data, and protects against bivariate outliers. In order to perform a skipped

610 correlation analysis, we first tested the assumptions of normality and homogeneity of

611 variance. The Henze-Zirkler's multivariate normality test (Trujillo-Ortiz et al., 2007)

612 indicated that the data was close to normally distributed, and the test for heterogeneity

613 indicated that the data have the same variance. Next, we estimated the robust centre of

614 the data using the minimum covariance determinant (MCD) estimator. The MCD

615 estimator is considered to be a robust estimator of the scatter and location of

616 multivariate data (Rousseeuw, 1984; Rousseeuw & van Drissen, 1999; Verboten &

617 Hubert, 2005). Bivariate outliers were then identified by using a projection technique –

618 data points were orthogonally projected by lines joining each data point to the robust

619 centre of the data cloud. Five bivariate outliers were removed using the box-plot rule

620 relying on the interquartile range (Carling, 2000), and skipped correlation was

621 computed on the remaining data. Following guidelines put forward previously (Pernet

622 et al., 2013), as the data were close to being normally distributed, we used a skipped

623 Spearman correlation analysis. A one-tailed skipped Spearman correlation analysis

624 showed a small positive correlation between the imitation and flanker compatibility

625   effects, which did not pass our statistical threshold, with the lower bound of the 95% CI

626   extended below zero (r (160) = 0.04, 95% CI [-0.12, ∞]; see Figure 4).
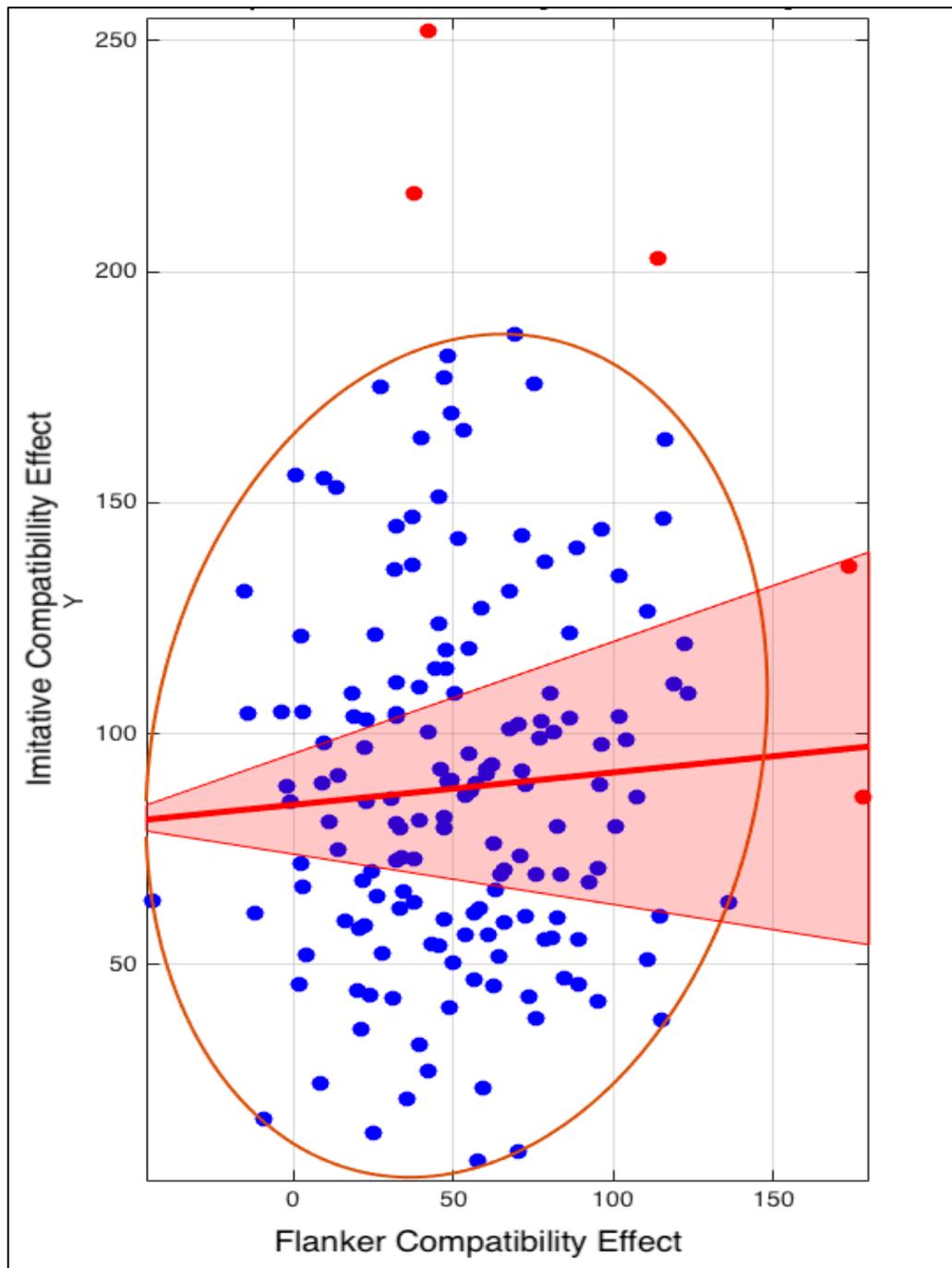

627
628 **Figure 4.** *Experiment 1 - Correlation Analysis.* A skipped Spearman correlation shows a small
629 positive correlation between the flanker and imitative compatibility effects that does not pass
630 our statistical thresholding. Abbreviations: RTms (reaction time in milliseconds). Dots in red are
631 the bivariate outliers.

632

633   Our results thus suggest that the compatibility effects across these tasks were

634   largely unrelated, and participants with greater interference in one task did not

635   experience a greater interference in the other task.

636   *Multiple regression analyses*

637   We also investigated the relationship between stable personality measures and

638   the general compatibility effect as measured on the SRC task. Tests for multicollinearity

639   indicated that a very low level of multicollinearity was present (*VIF* for all predictor

640   variables < 2). The base model included mean RT, sex, and a meanRT*sex interaction

641   term. The base model explained 33.6 % of the variance in the congruency effect

642   ($F_{(3,171)}$=28.88, p<.001, R^2=.34, f^2=0.51) and indicated a medium effect size (Cohen,

643   1992). Mean RT predicted the compatibility effect, with increasing CE as mean RT

644   increases (B=0.27, SEB=0.03, t(171)=8.02, p<.001, 95% CI [0.20; 0.34]). In addition to

645   mean RT, sex marginally predicted the compatibility effect (B=5.40, SEB=2.88,

646   t(171)=1.87,p=.06, [-0.29; 11.10]) with a higher compatibility effect for females than

647   males. The mean RT * sex interaction was also a predictor (B=0.10, SEB=0.03,

648   t(171)=3.01, p=.003, [0.03; 0.17]), suggesting that increases in mean RT predicted

649   larger increases in the compatibility effect for females (B=0.37, SEB=0.04, t(171)=8.43,

650   p=.001) compared to males (B=0.17, SEB=0.05, t(171)=3.32, p=.001). Results from the

651   base model are very similar to the results of prior work using a same SRC task and

652   analytical approach (Butler et al., 2015).

653   Agreeableness, extraversion, grandiose and vulnerability narcissism, empathy,

654   autistic-like and schizotypal trials, and alexithymia did not predict the general

655   compatibility effect above and beyond the base model (all p's > .11, all CIs overlapping

656   with zero; see Figure 5). Effect sizes attributable to the addition of the personality

657 variables (beyond the base model) indicated very small effects (Cohen's f^2 for all models

658 <0.01; Cohen, 1992). The multiple regression models are summarized in Supplementary

659 Table 3. Zero-order correlations are also consistent with the findings from the multiple

660 regression analyses, such that there are no relationships between stable personality

661 measures and CE (see Supplementary Table 4, Supplementary Figure 4).
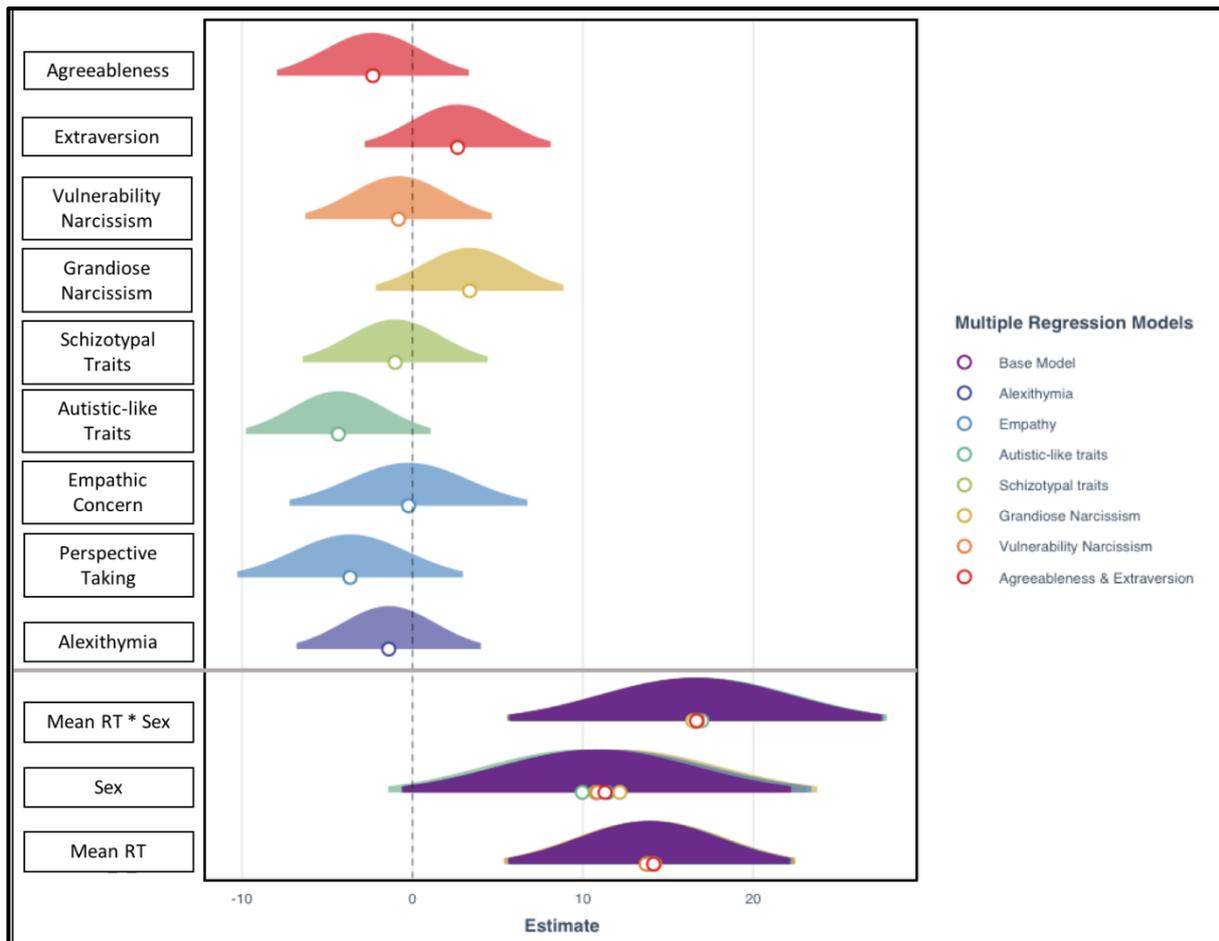
662
663 **Figure 5.** *Experiment 1 – Multiple Regression Analyses.* Values of standardised coefficients are
664 plotted for each predictor variable (personality trait) along with their corresponding
665 uncertainties (95% confidence interval width for a normal distribution for each estimate).
666 Coefficients are standardised by dividing by two standard deviation units according to Gelman
667 (2008). The base model consists in the bottom three predictor variables (depicted in violet) –
668 mean RT, Sex, and meanRT*Sex. Abbreviations: RT = Reaction Time. *N.B.* The circles on the
669 purple distributions represent the standardised co-efficients for the main effect of meanRT,
670 main effect of sex, and meanRT*sex interaction respectively for each of the models tested. That
671 is why there are multiple circles for components of the base model because the base model was
672 part of all the models test (that is, one model for each personality trait).

673

674   To evaluate the sex*trait interaction terms, we computed additional models –

675 each model consisted of the base model, one trait predictor, and the sex*trait

676   interaction term. For alexithymia, when the sex*trait term was included in the model,

677   the model explained 34.9% of the variance. The sex*alexithymia interaction term

678   marginally predicted the compatibility effect (B=0.48, SEB=0.27, t(169)=-1.71, p=0.09,

679   95% CI [-0.07, 1.03]), and explained an additional 1.3 % of the variance (ΔR2= .013,

680   F(1,169)=2.93,p<.0.09). A decrease in alexithymia marginally predicted an increase in

681   the compatibility effect only for males (B=-0.80, SEB=0.47, t(169)=-1.72, p=0.09) and

682   not for females (B=0.15, SEB=0.30, t(169)=0.49, p=0.62; see Figure 6A). The effect size

683   attributable to the addition of alexithymia and the sex*trait interaction term was very

684   small (Cohen's f^2 = 0.02).

685   For empathy, when the sex*trait term was included in the model, the model explained

686   36.9% of the variance. Sex*empathic concern predicted the compatibility effect above

687   and beyond the base model (B=1.62, SEB=0.74, t(167)=2.17, p=0.03, 95% CI [0.15,

688   3.10]) and explained an additional 1.8 % of the variance (ΔR2= .018, F(1,167)=4.73,

689   p=.031). Sex*perspective taking (B=-1.91, SEB=0.81, t(167)=-2.34, p=0.02, 95% CI [-

690   3.52, -0.30]) predicted the compatibility effect above and beyond the base model and

691   explained an additional 2.1 % of the variance (ΔR2= .021, F(1,167)=5.49, p=.021). An

692   increase in empathic concern marginally predicted a decrease in the compatibility effect

693   for males (B=-2.24, SEB=1.23, t(167)=-1.82, p=.07) whereas in females, there was a

694   trend for an increase in empathic concern predicting an increase in the compatibility

695   effect (B=1.01, SEB=0.85, t(169)=1.19, p=.24). An increase in perspective taking

696   predicted a decrease in the compatibility effect in females (B=-1.90, SEB=0.85, t(167)=-

697   2.24, p=.026). In males, there was a trend for an increase in perspective taking

698   predicting an increase in the compatibility effect (B=1.92, SEB=1.39, t(167)=1.38,

699   p=0.169; see Figure 6A). The effect size attributable to the addition of empathy and the

700   sex*trait interaction term was small (Cohen's f^2 = 0.05). None of the other sex*trait

interaction terms predicted the compatibility effect above and beyond the base model

(Cohen's f^2 for all models <0.02, Supplementary Figure 5, Supplementary Table 5).
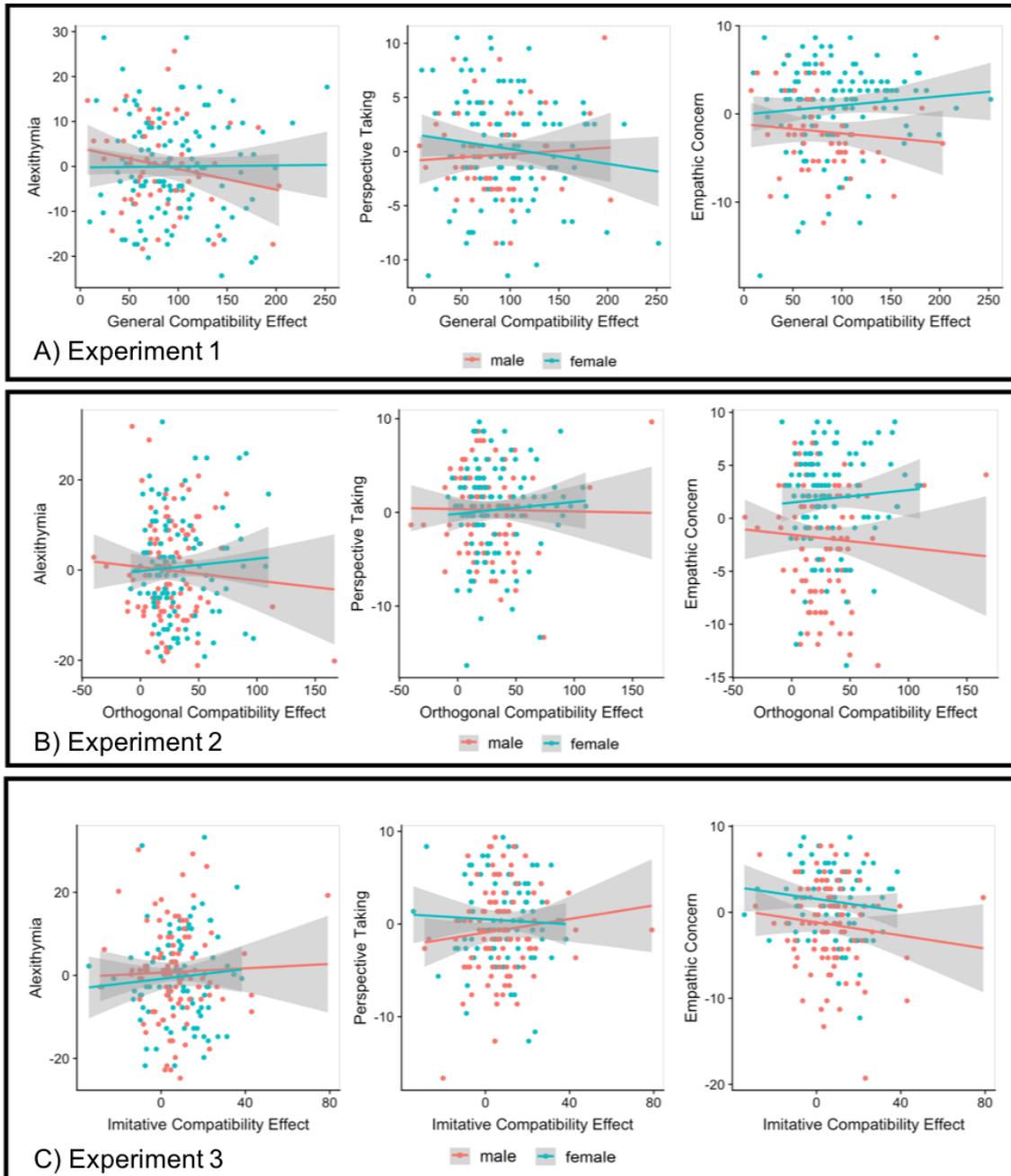
Figure 6. *Sex by trait interactions for Experiments 1, 2, 3.* Sex by trait interactions for alexithymia, perspective taking, and empathy personality traits for Experiments 1 (A), 2 (B), and 3 (C). X axis denotes the imitative compatibility effect in milliseconds, and Y axis denotes mean centred scores on the personality traits.

Discussion

The results demonstrate a sex difference in the general compatibility effect on the imitation task such that females showed a higher general compatibility effect than males, thus replicating the direction of results found previously (Butler et al., 2015; Genschow et al., 2017). A similar sex difference, however, was not found on the flanker task. Moreover, flanker and general compatibility effects were largely unrelated to each other. At first glance, therefore, this suggests that the sex difference may be tied to a form of cognitive control that is not shared between the two tasks, such as social (imitative) control.

Before we can make firm conclusions regarding the type of cognitive structure supporting the sex difference, however, we first consider some limitations of these results. First, the general compatibility effect is a sum of both spatial and imitative features. Participants respond with their right hand to a number cue – they are asked to lift their index or middle finger (for '1' or '2' respectively) while simultaneously observing a left hand making either the same or different finger movements. However, in this task, the observed and executed movements are not just imitatively compatible or incompatible, but also on the same or different side of space i.e. spatially compatible or incompatible. Thus, the task measures a general compatibility effect i.e. it does not measure the control of automatic imitation or the imitative compatibility effect independent of spatial compatibility effects (Catmur & Heyes, 2011). Thus, the sex difference may reflect a difference in spatial compatibility with respect to a finger location in space, as opposed to specifically in imitation control.

A second limitation to these initial conclusions is that the flanker task used in the current experiment employed fewer trials than those used in previous studies

735   where a sex difference was found (e.g. Stoet, 2011; Clayson et al., 2011). Therefore, a

736   lack of sex difference might reflect a lack of precision in measuring the effect. This might

737   also explain why we did not find a main effect of compatibility on the accuracy data in

738   the flanker task. Thus, although the current experiment employed a larger sample size

739   than previous studies using the flanker task, we are still cautious to interpret the lack of

740   evidence for the sex difference in the first experiment.

741   We also addressed an additional unrelated question in the current experiment.

742   In half of the compatible and incompatible trials, flanker arrows flipped arrow direction

743   during the trial between their initial presentation on the screen and the appearance of

744   the central arrow. However, when we analysed the flip and no-flip trials separately,

745   findings were similar and the direction of the results did not change. Therefore, we do

746   not think that the flipping of the arrow direction had any consequences on the measure

747   of interest.

748   Further, in the current experiment, we did not find any effect of the type of

749   emotional expression on automatic imitation. These findings add to previous research

750   that shows mixed evidence for a link between the emotional expression of the

751   interacting partner and the tendency to automatically imitate (Grerucci et al., 2013;

752   Crescentini et al., 2011; Rauchbauer et al., 2015). Finally, if we turn to consider the

753   effects of stable personality measures, a clear picture begins to emerge. Even in a more

754   socially meaningful context where emotional expressions are signalled, we further

755   support the claim that imitative control in general (across the entire group of

756   participants), shows a general invariance to stable dimensions of personality like

757   narcissism, agreeableness, extraversion, autistic-like and schizotypal traits (Butler et al.,

758   2015; Cracco et al., 2018). Of course, it is possible that the emotional expressions failed

759   to add to the social context of the task in a meaningful way. The face image signalling

760 the emotional expression was presented along with the hand image but they were two

761 separate images. This ensured that participants also paid attention to the hand image

762 which was the focus of the task. Further, it has been recently suggested that the link

763 between inferring an emotional state and the corresponding facial movements or

764 expressions is less clear than what has been previously suggested (Barrett et al., 2019).

765 It is possible, therefore, that participants ignored the face image, did not think of the

766 hand as connected to the face image, and did not infer the emotional state of the stimuli.

767 Even if this were true, however, we add a further large dataset to the prior work (Butler

768 et al., 2015; Cracco et al., 2018), which all show that personality variables have little

769 relationship to performance on the imitation task in general. We suggest that studies

770 purporting alternative patterns of relationship between imitation and personality

771 measures in general across the population (Chartrand & Bargh, 1999; Obhi et al., 2013;

772 Hogeveen & Obhi, 2013) perform powerful replications to enable a cumulative science

773 to develop (Munafo et al., 2017; Zwaan et al., 2018).

774   Although there were no clear main effects of personality across the entire

775 group, there was some suggestive evidence that the effect of personality on imitation

776 differed by sex. Given prior evidence linking automatic imitation and alexithymia, we

777 expected that an increase in automatic imitation would be predicted by a decrease in

778 alexithymia (Sowden et al., 2016). In the current experiment, this was true only for

779 males, and not for females. We further predicted that an increase in empathic concern

780 and perspective taking would predict an increase in automatic imitation (Chartrand &

781 Bargh, 1999). However, the current findings suggest that a decrease in empathic

782 concern predicts the compatibility effect in males, but not females, and a decrease in

783 perspective taking predicts the compatibility effect in females, but not males. It has been

784 suggested that males score higher on measures of alexithymia as compared to females

785 (Levant et al., 2009), and females score higher on empathic concern and perspective

786 taking as compared to males (Christov-Moore et al., 2014; Van der Graaff et al., 2013).

787 We had no *a priori* hypotheses however as to whether females and males would show a

788 link between personality and imitation in different directions. In addition, these

789 sex*trait interactions were small effects and contributed to only an additional 1.3%

790 (alexithymia) and 3.3 % (empathy) of the model. Thus, before making any firm

791 conclusions, these results require replication in order to confirm that they do not reflect

792 false positives as a result of sampling error.

793   A final potential limitation is that there were unequal samples in the first

794 experiment – 59 males and more than a hundred females. However, we do not think

795 that this affected overall findings because 1) although sample sizes are unequal, we do

796 not violate the homogeneity of variance assumption for the ANOVA, 2) unequal sample

797 sizes are problematic for factorial ANOVAs where there are unequal samples for two (or

798 more) between-group variables (which is not the case in the current experiment; Kao &

799 Green, 2008), and 3) we analyse our data using different approaches and find similar

800 results from all analyses, thus lending further support to our findings. Even so, for all

801 following experiments, we have kept sample sizes roughly equal.

802   Overall, therefore, these initial results from Experiment 1 demonstrate that

803 cognitive control systems may operate differently across individuals on some (sex), but

804 not other (personality), stable dimensions of individuals.

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Experiment 2

810   **Introduction**

811   In the second experiment, we extend findings from Experiment 1 and address

812   its limitations by making the following changes. First, in the automatic imitation task,

813   stimuli were displayed orthogonal to the response hand in order to minimise the effect

814   of spatial compatibility. Thus, instead of the general compatibility effect, we now

815   investigate the sex difference on the orthogonal compatibility effect. The orthogonal

816   compatibility effect allows us the measure automatic imitation dissociated from right-

817   left spatial compatibility effects, thus allowing for a more precise measure of the

818   imitative effect. Second, we again compare between males and females on the flanker

819   task but increase the number of trials such that both the imitation and flanker tasks are

820   equal. Similar to Experiment 1, we performed a correlational analysis to see whether

821   flanker and orthogonal compatibility effects were related to each other or not.

822   In Experiment 1, three sex*trait interactions, which covered empathic concern,

823   perspective taking, and alexithymia, predicted the general compatibility effect. Thus, in

824   order to further confirm these findings, we included empathy (empathic concern and

825   perspective taking) and alexithymia measures in Experiment 2 to investigate whether

826   these traits modulated the orthogonal compatibility effect.

827   **Method**

828   *Participants*

829   Two hundred and thirty-eight participants took part in this experiment for

830   monetary compensation (£6) or course credit. All participants provided informed

831   consent, had normal or corrected-to-normal vision, and were right-handed. Approval

832   was obtained from the Research Ethics and Governance Committee of the School of

833   Psychology at Bangor University. One participant was excluded because data on only

834   half the trials was recorded on the flanker task.

835   Participants were excluded if performance was three standard deviations away

836   from the group mean average performance per condition in terms of accuracy or

837   reaction time (N=15 for the imitation task, N=21 for the flanker task). For the imitation

838   task, the final sample included 223 participants (107 males, $Mean_{age}$ = 20., SD_{age} = 4.33;

839    $Mean_{age}$ and SD_{age} are based on 203 participants as some participants did not enter their

840   age in the demographic questionnaire). For the flanker task, the final sample included

841   217 participants (101 males, $Mean_{age}$ = 20.7, SD_{age} = 4.31; $Mean_{age}$ and SD_{age} are based

842   on 198 participants).

843   *Stimuli, tasks, and procedure*

844   *Automatic imitation task.* The automatic imitation task was similar to the one

845   used in Experiment 1, with the following changes: one, no face image was presented

846   during the task (Figure 1). Two, the hand stimuli were presented orthogonal to the

847   response (Figure 1). Three, there were 360 trials in total, which comprised six blocks of

848   60 trials, each of which included 30 compatible and 30 incompatible trials.

849   *Flanker task.* The flanker task was the same as Experiment 1 with only one

850   change – participants completed 360 trials in total, with 6 blocks of 60 trials each (30

851   compatible and 30 incompatible trials; Figure 1).

852   The order of the tasks was counterbalanced such that half the participants did

853   the flanker task first, whereas the remaining half did the imitation task first.

854   *Questionnaires.* Participants also completed two self-report questionnaires which

855   included the Interpersonal Reactivity Index (IRI; Davis, 1980), and the Toronto

856   Alexithymia Scale (TAS-20; Bagby et al., 1994). For more details on the measures used,

857   see the Supplementary Material.

Data Analysis

859   Accuracy and RT on the imitation and flanker tasks were recorded in the same

860   way as Experiment 1 and only correct trials were used to calculate RT. Trials on which

861   participants responded incorrectly, i.e. lifted the wrong finger, responded after 2000

862   ms, or before target onset (imitation = 5.59%; flanker = 5.97%) were all excluded from

863   the analysis.

864   Data were analysed in the same way as Experiment 1. For the imitation task, a

865   Sex*Compatibility interaction showing a higher compatibility effect for females

866   compared to males would indicate that the sex difference on the imitation task persists

867   even when stimuli are presented orthogonally to the response. Alternatively, similarly

868   sized compatibility effects between the sexes would suggest that reducing the spatial

869   component of the task largely removes the sex difference.

Results

Automatic imitation task

872   *Accuracy.* Average accuracy for both males and females for both compatible and

873   incompatible trials was over 92% (see Supplementary Figure 7, Supplementary Table

874   6). The 2 (compatibility: compatible, incompatible) x 2 (sex: male, female) mixed

875   ANOVA showed a main effect of compatibility such that participants were more

876   accurate on compatible trials than incompatible trials ($F(1, 221) = 96.22$, $p<.001$, $\eta_p^2 =$

877   0.30). The effect size for the main effect of compatibility is conventionally considered to

878   be large. The effect sizes for the main effect of sex ($F(1, 221) = 1.87$, $p = 0.17$, $\eta_p^2 = 0.008$)

879   and the Compatibility*Sex interaction ($F(1, 221) = 0.14$, $p = 0.71$, $\eta_p^2 < 0.001$) were close

880   to zero with p-values > 0.1 (see Supplementary Table 7).

881   *Reaction time.* Mean reaction times were between 435 and 485 milliseconds for

882   both males and females on both compatible and incompatible trials (see Figure 7,

883   Supplementary Table 6). The 2 (compatibility: compatible, incompatible) x 2 (sex: male,

884   female) mixed ANOVA (Figure 7) showed a main effect of compatibility such that

885   participants were slower to respond on incompatible trials than compatible trials ($F(1,$

886    $221) = 293.18$, $p<.001$, $\eta_p^2 = 0.56$). The effect size for the main effect of compatibility is

887   conventionally considered to be large. The main effect of sex had a relatively small

888   effect size and showed that females were generally slower than males ($F(1, 221) = 4.23$,

889    $p = 0.040$, $\eta_p^2 = 0.02$). There was a Compatibility*Sex interaction and the effect size is

890   conventionally considered to be a small effect ($F(1, 221) = 4.17$, $p = 0.042$, $\eta_p^2 = 0.02$;

891   Supplementary Table 7).

892   In order to interrogate our primary hypothesis regarding sex differences in the

893   imitation task, we computed compatibility effects separately for males and females, and

894   then compared them to each other. For both males and females, compatibility effects

895   had a large effect size (Cohen's $d_z > 1.0$) and the lower bound of the 95% confidence

896   interval was at least 0.82. When compatibility effects for males and females were

897   directly compared to each other, we found a mean difference of 6.98 ms in the direction

898   that was predicted i.e. the compatibility effect for females was greater than the

899   compatibility effect for males with the lower bound of the 95% confidence interval

900   above zero (Mean Difference = 6.98 ms, 95% CI[1.34, ∞], Cohen's d = 0.27 95% CI[0.05,

901   ∞]; Figure 7, Table 2B). The effect size was a small-to-medium effect, with the lower

902   bound of the 95% CI at 0.05.
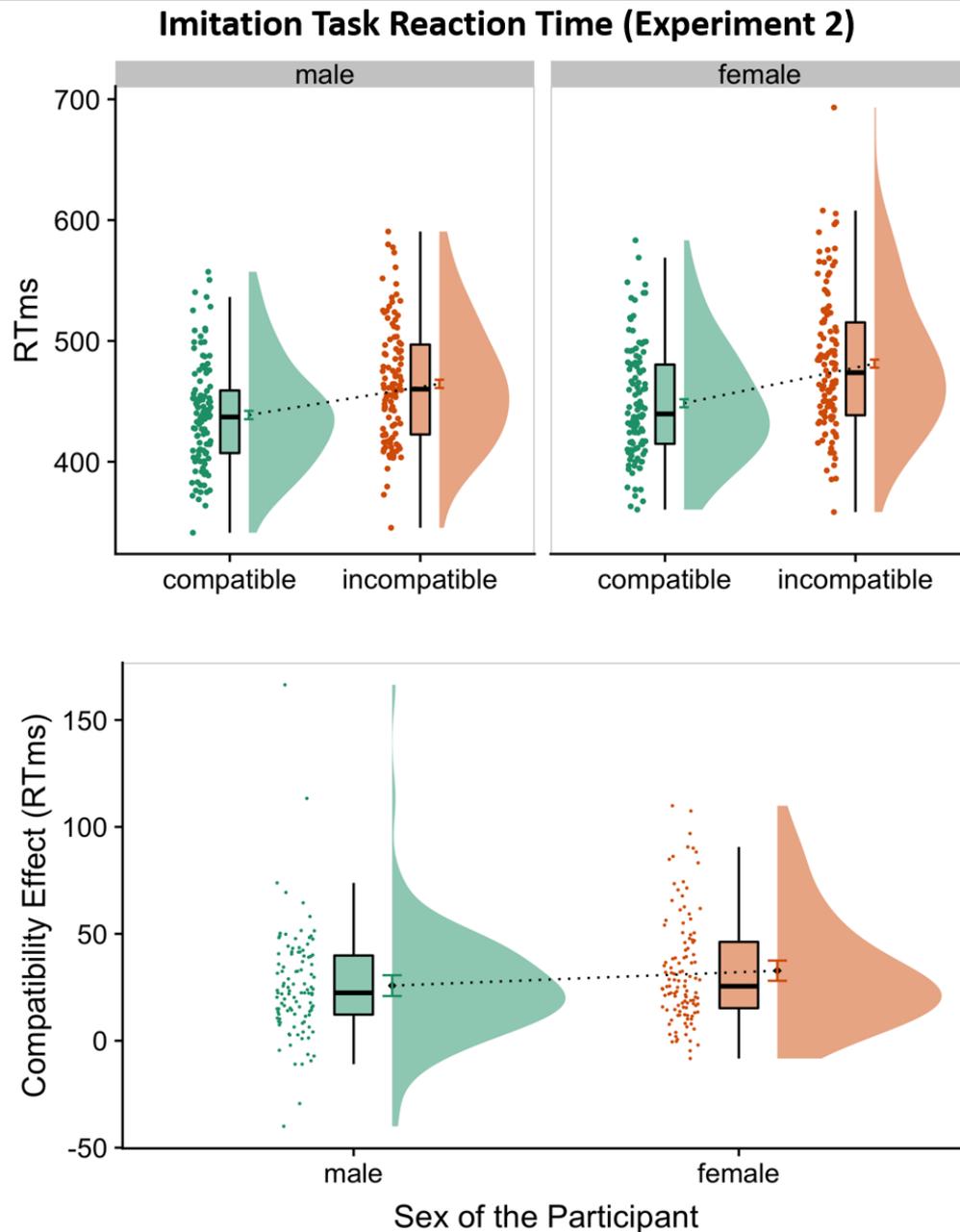
Figure 7. *Experiment 2 – Imitation Task Reaction Time.* Reaction time is reported in milliseconds (ms). The upper panel shows mean reaction times for compatible and incompatible conditions for both males and females. The lower panel shows the compatibility effect for both males and females. The compatibility effect is calculated by subtracting reaction times on compatible trials from incompatible trials. Error bars represent 95% confidence intervals. Abbreviations: RTms = reaction time in milliseconds.

The absolute size of the difference between the sexes as measured in original units (i.e., ms) is smaller than Experiment 1, as the orthogonal compatibility effect is smaller than the general compatibility effect measured in Experiment 1. Indeed, when

914   measured in original units, the compatibility effect in Experiment 2 is approximately

915   half the size of Experiment 1 and the same is true for the sex difference in compatibility

916   effect between the two experiments. However, the standardised effect size for the sex

917   difference is nearly identical across the two experiments (Exp. 1 = 0.28; Exp. 2 = 0.27).

918   Therefore, when measured in comparable units, which account for differences in

919   absolute values, these results suggest that the sex difference measured is quite

920   consistent across experiments. In sum, the orthogonal compatibility effect on the

921   imitation task differed as a function of sex in the same manner and to a similar degree

922   as Experiment 1, such that females had a greater orthogonal compatibility effect than

923   males.

924   *Flanker task*

925   *Accuracy.* Average accuracy was over 88% for both males and females on both

926   compatible and incompatible trials (see Supplementary Figure 8, Supplementary Table

927   6). A 2 (compatibility: compatible, incompatible) x 2 (sex: male, female) mixed ANOVA

928   showed a main effect of compatibility ($F(1, 215) = 151.33$, p<.001, $\eta_p^2 = 0.41$). The main

929   effect of compatibility showed that participants were more accurate on compatible

930   trials compared to incompatible trials. The main effect of sex showed that females had

931   lower accuracy overall compared to males ($F(1, 215) = 5.78$, p = 0.017, $\eta_p^2 = 0.03$). The

932   Compatibility*Sex interaction ($F(1, 215) = 3.17$, p = 0.076, $\eta_p^2 = 0.01$) showed that the

933   difference in accuracy between compatible and incompatible trials was greater for

934   females compared to males. The effect sizes for both the main effect of sex, and the

935   interaction were relatively small (see Supplementary Table 7).

936   *Reaction time.* Mean reaction times for both males and females for both

937   compatible and incompatible conditions was between 400 and 500 milliseconds (see

938 Figure 8, Supplementary Table 6). A 2 (compatibility: compatible, incompatible) x 2

939 (sex: male, female) mixed ANOVA (Figure 8) showed a main effect of compatibility such

940 that participants were slower to respond on incompatible trials than compatible trials

941 $(F(1, 215) = 1986.89, p<.001, \eta_p^2 = 0.90)$. The effect size for the main effect of

942 compatibility is conventionally considered to be large. The effect sizes for the main

943 effect of sex $(F(1, 215) = 0.03, p = 0.854, \eta_p^2 < 0.001)$. and the Compatibility*Sex

944 interaction $(F(1, 215) = 0.05, p = 0.816, \eta_p^2 < 0.001)$ were close to zero with p-values >

945 0.8 (see Supplementary Table 7).

946   To explore sex differences in the flanker task further, compatibility effects were

947 computed separately for males and females, and then compared to each other. For both

948 males and females, compatibility effects had a large effect size (Cohen's $d_z > 2.9$) with

949 the lower bound of the 95% confidence interval at least 2.62. When compatibility effects

950 for males and females were directly compared to each other, females showed a higher

951 compatibility effect than males, but the effect size was very small, with the lower bound

952 of the 95% confidence interval reaching -6.01ms (Mean Difference = 0.98 ms, 95% CI[-

953 6.01, ∞], Cohen's d = 0.03, 95%CI[-0.19, ∞]; Figure 8, Table 2B). The effect size was

954 close to zero with the lower bound of the confidence interval at -0.19 (below zero). A

955 Bayesian independent samples t-test showed that the null was 6 to 7 times more likely

956 than the alternative hypothesis $(BF_{01} = 6.58)$. Thus, although both males and females

957 separately showed a compatibility effect, there was a negligible difference between

958 males and females on the flanker compatibility effect.
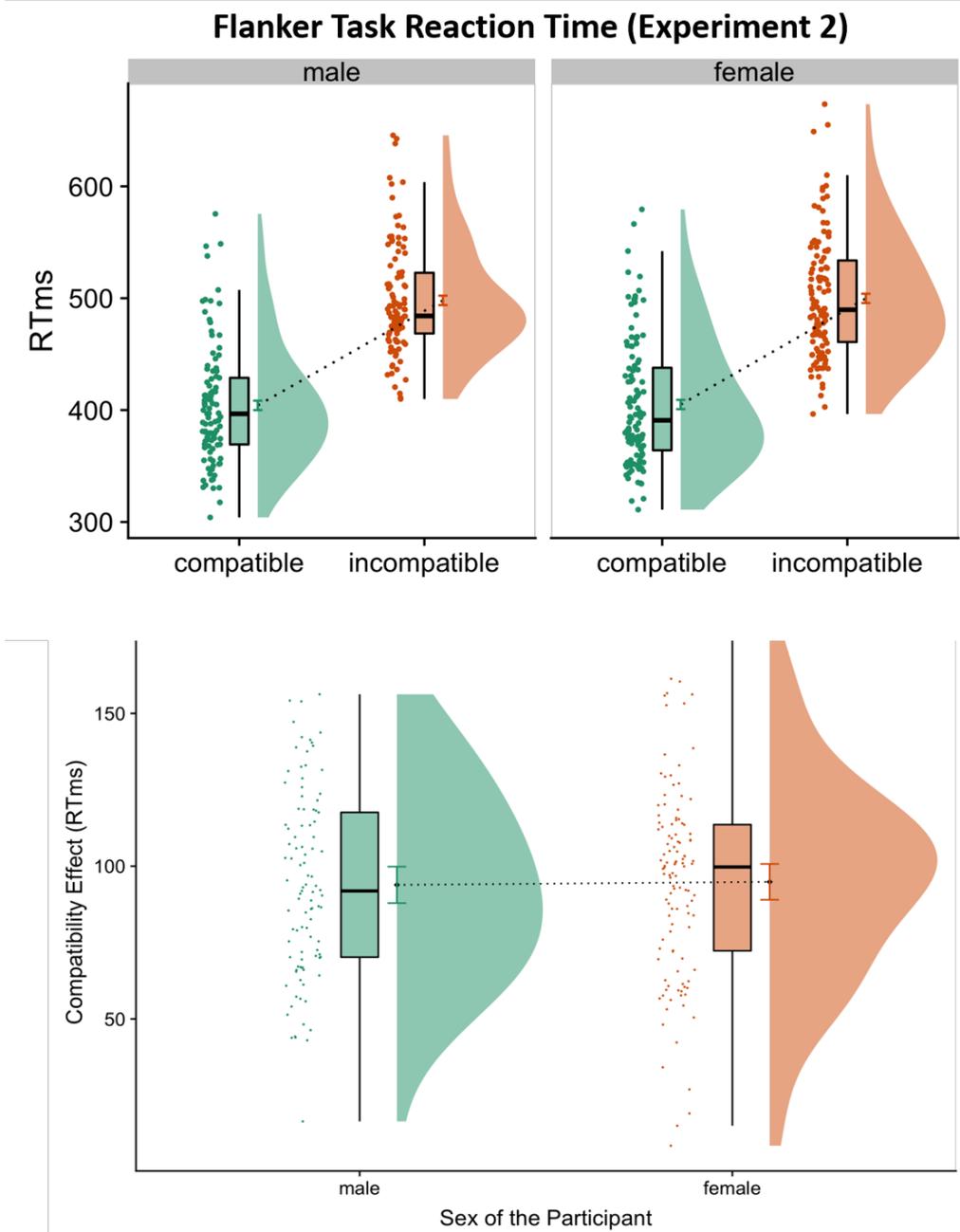
Figure 8. *Experiment 2 – Flanker Task Reaction Time.* Reaction time is reported in milliseconds (ms). The upper panel shows mean reaction times for compatible and incompatible conditions for both males and females. The lower panel shows the compatibility effect for both males and females. The compatibility effect is calculated by subtracting reaction times on compatible trials from incompatible trials. Error bars represent 95% confidence intervals. Abbreviations: RTms = reaction time in milliseconds.

Correlational analysis

In order to investigate whether the flanker and imitation compatibility effects were correlated, a one-tailed skipped correlation was performed. For the correlational

970   analysis, only those participants who performed both the tasks were included in the

971   analysis (N=205). As in Experiment 1, we also performed a more robust correlation

972   analysis. The data was not normally distributed, but was homoscedastic. Thus, we

973   performed a skipped Spearman correlation analysis on 191 participants as 14 bivariate

974   outliers were detected. Results indicated that flanker and imitation compatibility effects

975   showed a weak positive correlation that did not pass our statistical threshold

976   (Spearman r(191)=0.07, 95% CI [-0.07, ∞]; Figure 9). Our findings thus suggest that

977   flanker and imitative compatibility effects are largely unrelated, and interference on one

978   task did not predict interference on the other.
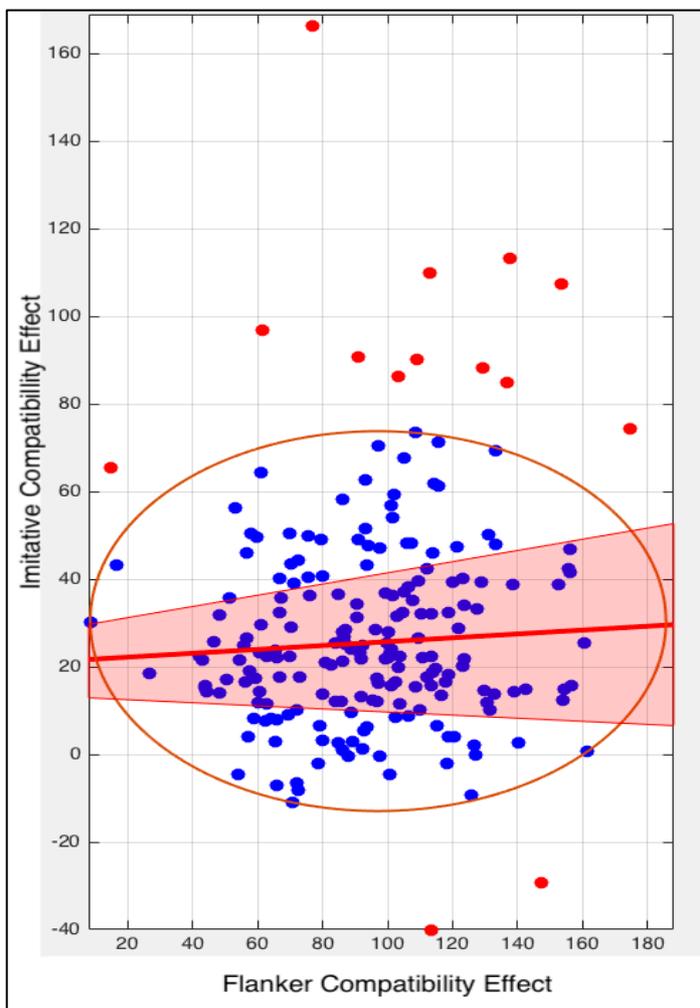
979
980   **Figure 9.** *Experiment 2 - Correlation Analysis.* A skipped Spearman correlation shows a small
981   positive correlation between the flanker and imitative compatibility effects that does not pass
982   our statistical thresholding. Abbreviations: RTms (reaction time in milliseconds). Dots in red are
983   the bivariate outliers.

Multiple regression analyses

985   We also investigated the relationship between personality variables (empathy

986   and alexithymia) and the orthogonal compatibility effect as measured on the SRC task.

987   Tests for multicollinearity indicated that a very low level of multicollinearity was

988   present (*VIF* for all predictor variables < 2). The base model (which included mean RT,

989   sex, and the mean RT*Sex interaction) explained 16.2% of the variance in the

990   congruency effect (F(3,204)=13.13, p<.001, R2=.16, f^2 = 0.19) and indicated a medium

991   effect. Mean RT predicted the orthogonal compatibility effect (B=0.19, SEB=0.03,

992   t(204)=5.36,p<.001, [0.12; 0.26]) with increasing CE as mean RT increased. Sex did not

993   predict the orthogonal compatibility effect (B=2.14, SEB=1.67, t(204)=1.27,p=.21, [-

994   1.19; 5.47]). The mean RT * sex interaction (B=0.07, SEB=0.03, t(204)=1.90,p=.06, [-

995   0.002; 0.13]) suggested that increases in mean RT predicted larger increases in the

996   compatibility effect for females (B=0.25, SEB=0.05, t(204)=5.45, p<.001) compared to

997   males (B=0.12, SEB=0.05, t(204)=2.33, p<.001).

998   Alexithymia and empathy (empathic concern and perspective taking) did not

999   predict the orthogonal compatibility effect above and beyond the base model (all p's >

1000   0.03, all CIs overlapping with zero; see Figure 10). Effect sizes attributable to the

1001   addition of the personality variables (beyond the base model) indicated extremely small

1002   effects (Cohen's f^2 = <.001 for alexithymia and Cohen's f^2 = .005 for empathy). The

1003   multiple regression models are summarized in Supplementary Table 8. Zero-order

1004   correlations are also consistent with the findings from the multiple regression analyses

1005   (see Supplementary Table 9, Supplementary Figure 9).
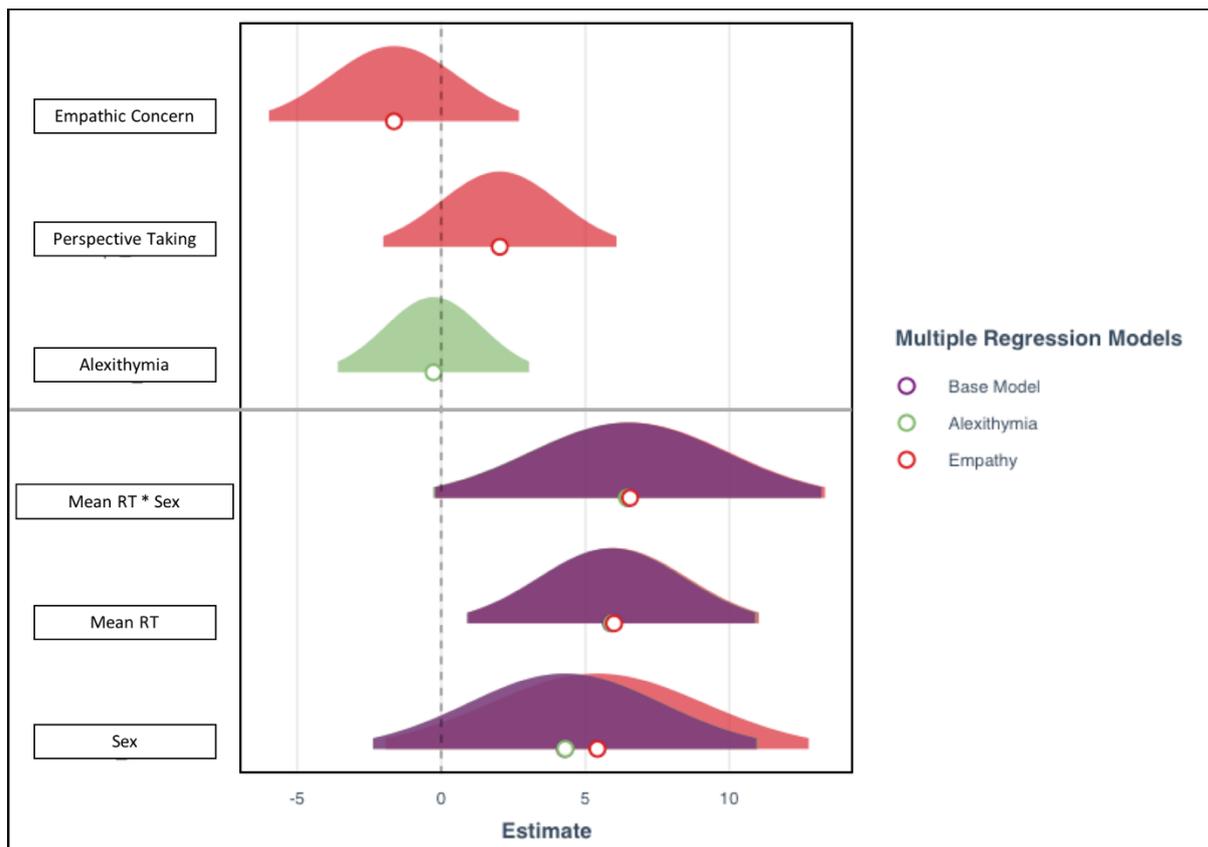
1006
1007 **Figure 10.** *Experiment 2 – Multiple Regression Analyses.* Values of standardised coefficients are
1008 plotted for each predictor variable (personality trait) along with their corresponding
1009 uncertainties (95% confidence interval width for a normal distribution for each estimate).
1010 Coefficients are standardised by dividing by two standard deviation units according to Gelman
1011 (2008). The base model consists in the bottom three predictor variables (depicted in violet) –
1012 mean RT, Sex, and meanRT*Sex. Abbreviations: RT = Reaction Time. *N.B.* The circles on the
1013 purple distributions represent the standardised co-efficients for the main effect of meanRT,
1014 main effect of sex, and meanRT*sex interaction respectively for each of the models tested. That
1015 is why there are multiple circles for components of the base model because the base model was
1016 part of all the models test (that is, one model for each personality trait).

1017

1018   To evaluate the sex*trait interaction terms, we computed additional models –

1019 each model consisted of the base model, one trait predictor, and the sex*trait

1020 interaction term. None of the sex*trait interaction terms predicted the orthogonal

1021 compatibility effect above and beyond the base model (all ps>0.3, all CIs overlapping

1022 with zero; Figure 6B, Supplementary Figure 10). Effect sizes attributable to the addition

1023 of the sex*trait interaction terms (beyond the base model) indicated extremely small

1024 effects (Cohen's f^2 = 0.01 for both alexithymia and empathy). The multiple regression

1025 models are summarized in Supplementary Table 10.

1026

Discussion

1028   As in Experiment 1, results indicated a clear sex difference in the orthogonal

1029   compatibility effect such that females showed a higher orthogonal compatibility effect

1030   compared to males on the automatic imitation task. The sex difference persisted on the

1031   imitation task in spite of presenting stimuli orthogonal to the response. However, this

1032   sex difference on the RT compatibility effect was not found on the flanker task even

1033   after increasing the number of trials. Further, the correlational analysis suggested that

1034   flanker and orthogonal compatibility effects were only marginally correlated with each

1035   other and explained only 0.8% of the variance. Thus, greater interference on one task is

1036   able to predict only a very small amount of interference on the other task.

1037   Thus, across Experiments 1 and 2, we show a lack of consistent evidence for a

1038   sex difference in the flanker task. However, the interpretation of the sex difference on

1039   the imitation task still has two potential limitations. One, while the presentation of

1040   orthogonal stimuli reduces spatial compatibility effects on the left-right axis, they do not

1041   rule out the possibility of orthogonal spatial compatibility effects i.e. the propensity of

1042   participants to show an advantage for an up-right and down-left pairing (Weeks &

1043   Proctor, 1999; Cho & Proctor, 2003; Weeks, Proctor, & Beyak, 1994). For instance, when

1044   stimuli were presented orthogonal to the response hand (see Figure 1), the index finger

1045   was always below the middle finger, and the participant's index finger was to the left

1046   side of space. Thus, a preference for responding to "up" stimuli with a right response

1047   and "down" stimuli with a left response may be observed along with imitative effects on

1048   the automatic imitation task used in the current experiment. Thus, the sex difference

1049 may reflect a difference on orthogonal spatial effects as opposed to purely imitative

1050 effects.

1051   Two, the stimuli used in both Experiments 1 and 2 were those of a female

1052 model. We did not manipulate the sex of the stimulus, and therefore, the sex difference

1053 can either reflect a genuine difference between males and females, or an in-group bias.

1054 A difference between male and female participants (irrespective of the sex of the

1055 stimulus) would reflect distinct (or partially distinct) cognitive mechanisms underlying

1056 imitative or spatial control as a function of sex. On the contrary, an in-group bias or

1057 own-sex bias would suggest that sex differences as evidenced previously on the

1058 automatic imitation task (Butler et al., 2015; Genschow et al., 2017) do not actually

1059 reflect a sex difference - females show a higher compatibility effect because they favour

1060 members of the in-group i.e. of their own sex compared to members of the out-group i.e.

1061 of the opposite sex (Rudman & Goodwin, 2004; Brown, 1995; Rauchbauer et al., 2015;

1062 Gleibs et al., 2016).

1063   Finally, in terms of personality measures, empathy and alexithymia (and

1064 sex*trait interactions) did not modulate the orthogonal compatibility effect. Although

1065 we found suggestive evidence in Experiment 1 for a small link between personality

1066 traits (alexithymia and empathy) and imitation that differed between the sexes, the

1067 current experiment did not replicate these findings. Therefore, overall, these results

1068 provide limited support for a link between personality traits and automatic imitation,

1069 and confirm and replicate findings from previous large sample studies (Butler et al.,

1070 2015; Cracco et al., 2018) that suggest automatic imitation is largely invariant to stable

1071 traits of personality.

1072

1073 **Experiment 3**

1074 **Introduction**

1075   Experiment 3 addressed two remaining issues. First, we measured the imitative

1076 compatibility effect independently from the spatial compatibility effect, in order to

1077 estimate whether the sex difference reflects a spatial or more specialised (social)

1078 aspects of cognitive control. Second, we assessed the extent to which the sex difference

1079 reflects a basic difference between males and females and/or an in-group bias based on

1080 sex.

1081   To separate imitative and spatial components of the task, we used a modified

1082 version of the SRC task of automatic imitation that allowed us to manipulate imitative

1083 and spatial effects separately (Catmur & Heyes, 2011; Boyer et al., 2012; Bertenthal et

1084 al., 2006). A sex difference on spatial compatibility alone would indicate that the sex

1085 difference observed in Experiments 1 and 2 can be explained by differences associated

1086 with processing spatial information. Alternatively, a sex difference on imitative

1087 compatibility alone, would suggest that greater compatibility effects for females reflects

1088 a difference in the control of automatic imitation specifically.

1089   To compare a sex difference account with an in-group bias account of our

1090 findings so far, we manipulated the sex of the stimuli used in the SRC task and again

1091 tested male and female participants. A greater compatibility effect for females for

1092 female stimuli compared to male stimuli would indicate that an own-sex bias

1093 contributes to the sex difference observed on the automatic imitation task.

1094 Alternatively, a sex difference on the task and relative invariance to the sex of the

1095 stimuli would suggest that there is a basic control mechanism that differs between

1096 males and females that seems resistant to possible contextual factors, such as group

1097 biases.

1098   In order to investigate whether personality variables influence automatic

1099 imitation, in Experiment 3, we included all personality variables included in Experiment

1100 1 (alexithymia, empathy, autistic-like and schizotypal traits, narcissism, extraversion,

1101 and agreeableness). In Experiment 1 and 2, the compatibility effect measured on the

1102 imitation task was a composite of spatial and imitative effects. Therefore, the invariance

1103 of the compatibility effect may be related to spatial effects as opposed to imitative

1104 effects. Therefore, we included all the personality measures in order to investigate

1105 whether imitative compatibility when measured independently of spatial effects is also

1106 invariant to stable personality traits.

1107 **Method**

1108 *Participants*

1109   Two hundred and one participants took part in this experiment for monetary

1110 compensation (£6) or course credit. All participants provided informed consent, had

1111 normal or corrected-to-normal vision, and were right-handed. Approval was obtained

1112 from the Research Ethics and Governance Committee of the School of Psychology at

1113 Bangor University. Participants were excluded if performance was 3 standard

1114 deviations away from the group mean average performance per condition in terms of

1115 accuracy or reaction time on the imitation task (N = 12). The final sample included 189

1116 participants (97 males, $Mean_{age}$ =21.4, SD_{age} = 4.08, age range = 18 to 42) ($Mean_{age}$ and

1117 SD_{age} are based on 182 participants as 7 participants did not enter their age in the

1118 demographics questionnaire).

1119 *Stimuli, tasks, and procedure*

Automatic imitation task. The automatic imitation task was similar to the one

used in Experiment 2, with the following changes: one, stimuli were not presented

orthogonally to the response. Two, we calculated an imitative compatibility effect

independent of the spatial compatibility effect (Catmur & Heyes, 2011). For this, both

left- and right-hand images were used as stimuli, but participants always responded

with their right hand. This resulted in eight trial types and four conditions of interest

(Figure 1):

1.	imitatively and spatially compatible (for example, when participants are
cued to lift their index finger, and watch an index finger lift of the left hand, the
observed finger movement is both spatially and imitatively compatible to the executed
movement),

2.	imitatively and spatially incompatible (for example, when participants are
cued to lift their index finger, and watch a middle finger lift of the left hand, the
observed finger movement is both spatially and imitatively incompatible to the
executed movement),

3.	imitatively compatible and spatially incompatible (for example, when
participants are cued to lift their middle finger, and watch a middle finger lift of the
right hand, the observed finger movement is imitatively compatible, but spatially
incompatible to the executed movement),

4.	imitatively incompatible and spatially compatible (for example, when
participants are cued to lift their middle finger, and watch an index finger lift of the right
hand, the observed finger movement is imitatively incompatible, but spatially
compatible to the executed movement).

1143   Thus, participants performed the same (imitatively compatible) or different

1144   (imitatively incompatible) movement on the same (spatially compatible) or different

1145   (spatially incompatible) side of space.

1146   A third change in comparison to Experiment 2, is that in order to investigate

1147   whether the sex difference was due to an own-sex bias, the hand stimuli presented

1148   included 4 female and 4 male hands. The hand stimuli were chosen based on a pilot

1149   study. In the pilot study (see Supplementary Material), eighteen hand stimuli were

1150   rated by 51 participants on a scale of 1 to 9 with one being most masculine, 5 being

1151   neutral, and 9 being most feminine. Four hand stimuli rated as most masculine, and four

1152   hand stimuli rated as most feminine were chosen for the current experiment. There

1153   were 360 total trials, with 90 trials per condition. Timing information and pseudo-

1154   randomisation was the same as in Experiment 1 and 2.

1155   *Questionnaires.* Participants also completed a range of self-report questionnaires

1156   which included the Mini International Personality Item Pool (mini IPIP; Donnellan et al.,

1157   2005; the Short Autism Spectrum Quotient (AQ-10 Adult; Baron-Cohen et al., 2001), the

1158   Brief Schizotypal Personality Questionnaire (SPQ-B; Raine & Benishay, 2005), the

1159   Narcissistic Personality Inventory (NPI-16; Ames et al., 2006), the Hypersensitivity

1160   Narcissism Scale (HSNS; Hendin & Cheek, 1997), the Interpersonal Reactivity Index (IRI;

1161   Davis, 1980), and the Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994). For more

1162   details on the measures used, see the Supplementary Material.

1163   In order to confirm that participants perceived male and female stimuli

1164   differently, participants also rated the hand stimuli used in the experiment after they

1165   completed the task. Participants were asked to rate the stimuli on a scale of 1 to 9, with

1166   1 being extremely masculine and 9 being extremely feminine.

Data Analysis

Accuracy and RT on the imitation task were recorded in the same way as

Experiment 1 and 2 and only correct trials were used to calculate RT. Trials on which

participants responded incorrectly, i.e. lifted the wrong finger, responded after 2000

ms, or before target onset (7.41 %) were all excluded from the analysis.

A key aim of our study was to investigate whether the sex difference and/or in-

group bias exists in imitative and/or spatial compatibility effects (and not whether/how

such differences differ between the two types of effect). For this purpose, therefore, we

performed analyses separately on the spatial and imitative compatibility effects. For

each compatibility effect separately, we performed a 2 (compatibility: incompatible,

compatible) x 2 (stimulus sex: male hand, female hand) x 2 (participant sex: male,

female) mixed ANOVA on the RT and accuracy data. Based on prior research (Catmur &

Heyes, 2011; Gowen et al., 2016; Marsh et al., 2016; Darda et al., 2018), we expected a

main effect of spatial and imitative compatibility such that RT would be higher, and

accuracy would be lower on spatially incompatible trials compared to spatially

compatible trials, and on imitatively incompatible trials compared to imitatively

compatible trials.

In addition, a Sex*Compatibility interaction for spatial compatibility (such that

females show a higher spatial compatibility effect that males) would be expected if the

sex difference observed in Experiments 1 and 2 was largely driven by the spatial

component of the task. In contrast, a Sex*Compatibility interaction for imitative

compatibility (such that females show a higher imitative compatibility effect than

males) would suggest that the sex difference is largely a reflection of the imitative

component of the task.

1191   Alternatively, if the sex difference in the spatial or imitative compatibility effect

1192   is because of an own-sex bias, we would expect a three-way interaction

1193   (Sex*Compatibility*Stimulus Sex) such that females would be more interfered by a

1194   female stimulus, and males would be more interfered by a male stimulus i.e. females

1195   would show a higher compatibility effect than males for female stimuli compared to

1196   male stimuli.

1197   As in Experiment 1, the interaction effect was central to testing our primary

1198   hypotheses, and thus, we calculated compatibility effects for male and female hand

1199   stimuli separately and independently for both male and female participants. To do so,

1200   we computed the mean difference and 95% confidence intervals between compatible

1201   and incompatible conditions across the levels of stimulus sex and participant sex.

1202   Spatial compatibility was calculated as RT on spatially incompatible trials minus RT on

1203   spatially compatible trials. Imitative compatibility was calculated as RT on imitatively

1204   incompatible trials minus imitatively compatible trials. In order to directly estimate the

1205   size of the difference in spatial and imitative compatibility effects between males and

1206   females, we then again computed the mean differences between the sexes and 95%

1207   confidence intervals. We used one-tailed 95% confidence intervals as we had a

1208   directional hypothesis that females would have a higher spatial or imitative

1209   compatibility effect than males.

1210   For the secondary analyses, multiple regression analyses were performed in the

1211   same way as Experiments 1 and 2 in order to investigate whether personality variables

1212   and sub-clinical traits modulate automatic imitation when measured independent of

1213   spatial effects.

1214

Results

Spatial Compatibility

Accuracy. Average accuracy was over 92% for both males and females for all conditions of compatibility and stimulus sex (see Supplementary Figure 11, Supplementary Table 11). A 2 (compatibility: incompatible, compatible) x 2 (stimulus sex: male hand, female hand) x 2 (participant sex: male, female) mixed ANOVA showed a main effect of compatibility such that participants were more accurate on compatible trials than incompatible trials ($F(1,187) = 563.35$, $p<.001$, $\eta_p^2 = 0.75$; Supplementary Figure 11). The effect size of the main effect of compatibility was large. The main effect of stimulus sex suggested that participants were more accurate when observing male hand stimuli as compared to female hand stimuli ($F(1,187) = 335.47$, $p<.001$, $\eta_p^2 = 0.64$). The Compatibility*Stimulus Sex interaction suggested that the difference in accuracy between incompatible and compatible trials was overall bigger for female stimuli compared to male stimuli (($F(1,187) =202.31$, $p<.001$, $\eta_p^2 = 0.52$), Supplementary Figure 11). All other main effects and interactions' effect sizes were relatively small with high p-values (see Supplementary Table 12).

Reaction time. Mean reaction times for both males and females on all conditions of compatibility and stimulus sex were between 415 to 475 milliseconds (see Figure 11, Supplementary Table 11). A 2 (compatibility: incompatible, compatible) x 2 (stimulus sex: male hand, female hand) x 2 (participant sex: male, female) mixed ANOVA (Figure 11) showed a main effect of compatibility such that participants were slower to respond on spatially incompatible trials compared to spatially compatible ($F(1,187) = 459.71$, $p<.001$, $\eta_p^2 = 0.71$). The effect size of the main effect of compatibility was large. The main effect of stimulus sex had a medium effect size, and suggested that overall participants

1239 responded slower to female hand stimuli than male hand stimuli (F(1,187) = 5.63, p =

1240 0.019, η_p^2 = 0.03).

1241   The Sex*Compatibility interaction was a small-to-medium effect with a p-value

1242 of 0.04 (F1,187) = 4.24, p = 0.041, η_p^2 = 0.02). To interrogate the sex difference in spatial

1243 compatibility, we computed the difference in compatibility effects between males and

1244 females, collapsed across all conditions of stimulus sex. Females showed a higher

1245 compatibility effect than males by 6.53 ms, and the lower bound of the 95% CI was over

1246 zero at 2.02ms (Mean difference = 6.53ms, 95% CI [2.02, ∞], Cohen's d = 0.24, 95% CI

1247 [0.07, ∞]; Figure 13A, Table 2C). The effect size was a small-to-medium effect, and the

1248 lower bound of the 95% CI was above zero at 0.07.

1249   The three-way (Compatibility*Stimulus Sex*Sex) interaction (F(1,187) = 1.77,

1250 p=0.185, η_p^2 = 0.01) showed a trend such that females had a higher compatibility effect

1251 for female hand stimuli compared to male hand stimuli, and males had a higher

1252 compatibility effect for male hand stimuli compared to female hand stimuli, although

1253 the effect size was close to zero (Figure 11). All other effect sizes for main effects or

1254 interactions were close to zero (see Supplementary Table 12).

1255   In order to investigate whether an in-group bias explains the sex difference in

1256 spatial compatibility, we computed compatibility effects on all levels of participant sex

1257 and stimulus sex. For both males and females, spatial compatibility effects were present

1258 when observing both male (Cohen's d_z > 1.25) as well as female stimuli (Cohen's d_z >

1259 1.10). There was a trend for females showing a higher compatibility effect for female

1260 stimuli compared to male stimuli (Mean difference = 2.74 ms, 95% CI [-2.40, ∞],

1261 Cohen's d_z = 0.09, 95% CI[-0.08, ∞]), and for males showing a higher compatibility

1262 effect for male stimuli compared to female stimuli (Mean difference = 3.19, 95% CI [-

1263   2.12, ∞], Cohen's d_z = 0.10; 95% CI[-0.07, ∞]), but these were relatively small effect

1264   sizes (see Figure 11).
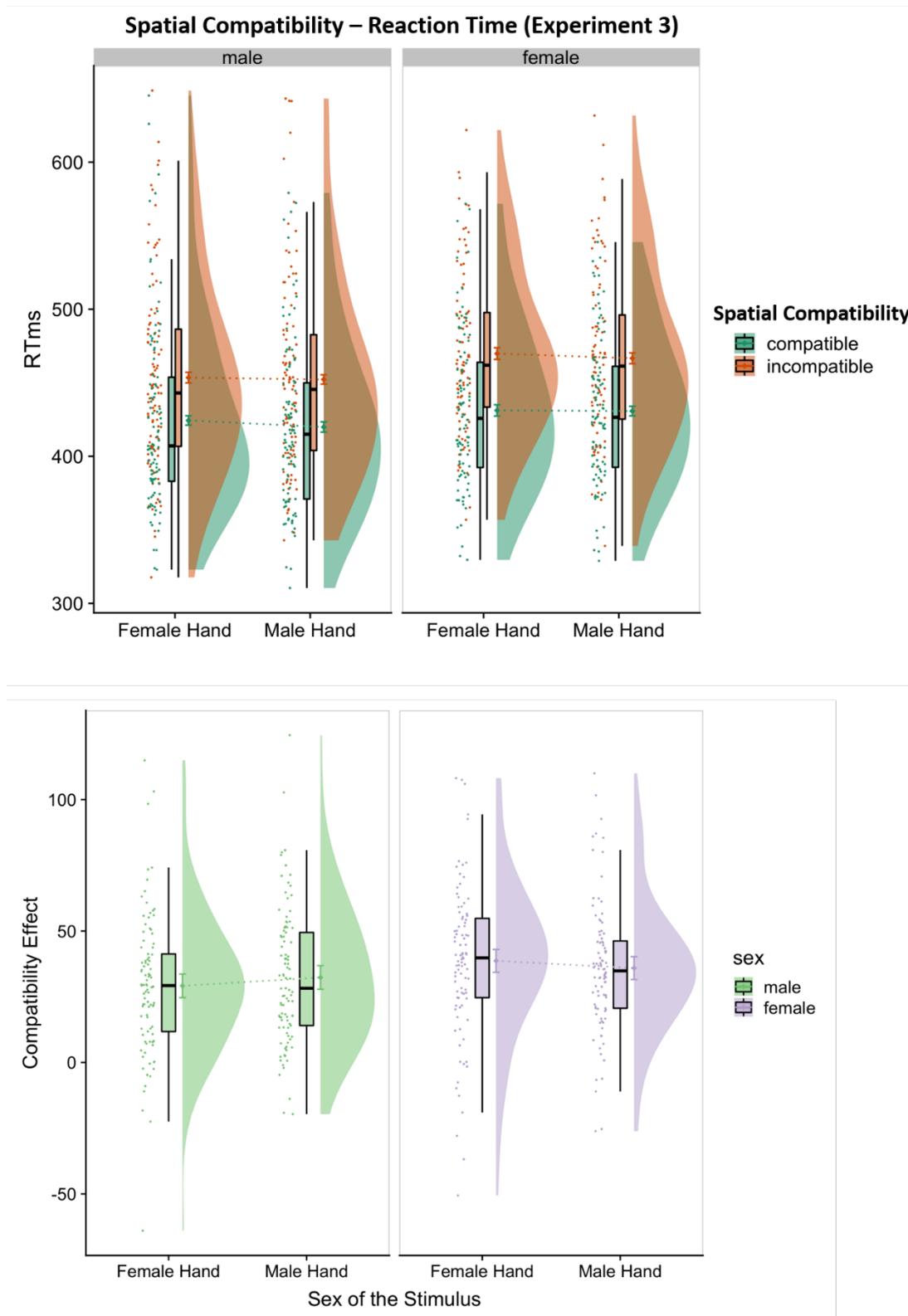
1265

1266   **Figure 11.** *Experiment 3 – Spatial Compatibility Reaction Time.* Reaction time is reported in
1267   milliseconds (ms). The upper panel shows mean reaction times for compatible and

1268 incompatible conditions for both males and females, when responding to both male and female
1269 hand stimuli. The lower panel shows the compatibility effect for both males and females when
1270 responding to both male and female hand stimuli. The compatibility effect is calculated by
1271 subtracting reaction times on compatible trials from incompatible trials. Error bars represent
1272 95% confidence intervals. Abbreviations: RTms = reaction time in milliseconds.

1273

1274 *Imitative Compatibility*

1275 *Accuracy*. Average accuracy for both males and females for all conditions of

1276 stimulus sex and compatibility was above 87% (see Supplementary Figure 12,

1277 Supplementary Table 11). A 2 (compatibility: incompatible, compatible) x 2 (stimulus

1278 sex: male hand, female hand) x 2 (participant sex: male, female) mixed ANOVA

1279 (Supplementary Figure 12) showed a main effect of compatibility (F(1,187) = 205.65,

1280 p<.001, η_p^2 = 0.52) such that participants were more accurate on compatible trials than

1281 incompatible trials. The effect size of the main effect of compatibility was large. The

1282 main effect of stimulus sex (F(1,187) = 335.47, p<.001, η_p^2 = 0.64) suggested that

1283 participants were more accurate when observing male hand stimuli as compared to

1284 female hand stimuli. The Compatibility*Stimulus Sex interaction (F(1,187) = 162.98,

1285 p<.001, η_p^2 = 0.46) suggested that the difference in accuracy between compatible and

1286 incompatible trials was bigger for female stimuli compared to male stimuli (see

1287 Supplementary Figure 12). All other main effects and interactions were relatively small

1288 or close to zero with high p-values (see Supplementary Table 12).

1289 *Reaction time.* Mean reaction times were between 430 and 460 milliseconds for

1290 both males and females on all conditions of compatibility and stimulus sex (see Figure

1291 12, Supplementary Table 11). A 2 (compatibility: incompatible, compatible) x 2

1292 (stimulus sex: male hand, female hand) x 2 (participant sex: male, female) mixed

1293 ANOVA showed a main effect of compatibility (F(1,187) = 54.96, p<.001, η_p^2 = 0.23) such

1294 that participants were slower to respond on imitatively incompatible trials compared to

imitatively compatible. The effect size of the main effect of compatibility was large. The main effect of stimulus sex was a small-to-medium effect with a p-value of 0.02 and suggested that participants responded slower to female hand stimuli than male hand stimuli (F(1,187) = 5.70, p = 0.018, η_p^2 = 0.03).

The effect size for the Sex*Compatibility interaction was close to zero with a p-value of 0.52 (F(1,187) = 0.41, p = 0.52, η_p^2 = 0.002). Given the importance to our primary research question regarding sex differences in the compatibility effect, we interrogated the RT data further by computing the difference in compatibility effects between males and females, collapsed across all conditions of stimulus sex. Although females showed a marginally higher compatibility effect than males by 1.33 ms, the lower bound of the 95% CI was below zero at -2.15 ms. The effect size was small with the lower bound of the 95% CI below zero at -0.10 (Mean difference = 1.33, 95% CI [-2.15, ∞], Cohen's d = 0.06, 95 % CI[-0.10, ∞]; see Figure 13B, Table 2C).

The three-way (Compatibility*Stimulus Sex*Participant Sex) interaction (F(1,187) = 3.86, p=0.051, η_p^2 = 0.02) was a relatively small effect. All other main effects or interactions had effect sizes close to zero with high p-values (see Figure 12, Supplementary Table 12).

In order to investigate the three-way interaction and explore whether the sex difference can be explained by an in-group bias, we computed compatibility effects on all levels of participant sex and stimulus sex. For both males and females, imitative compatibility effects were present when observing both male (Cohen's d_z > 0.2) as well as female stimuli (Cohen's d_z > 0.3). However, there was not even a trend in the direction we predicted i.e. females did not show a higher compatibility effect for female stimuli compared to male stimuli (Cohen's d_z = -0.10), and for males showing a higher

1319   compatibility effect for male stimuli compared to female stimuli (Cohen's d_z = -0.18). On

1320   the contrary, the direction of the interaction was contrary to our hypothesis i.e. females

1321   showed a higher compatibility effect for male stimuli compared to female stimuli, and

1322   males showed a higher compatibility effect for female stimuli compared to male stimuli,

1323   but these effects were small (see Figure 12). As such, not only are these effects relatively

1324   small, they are also inconsistent with the sex difference being a result of an ingroup bias

1325   based on the sex of the interaction partner.

1326   In sum, our results indicated a sex difference in spatial compatibility, but not

1327   imitative compatibility. An in-group bias/own-sex bias did not explain the sex

1328   difference found in the spatial compatibility effect.

1329
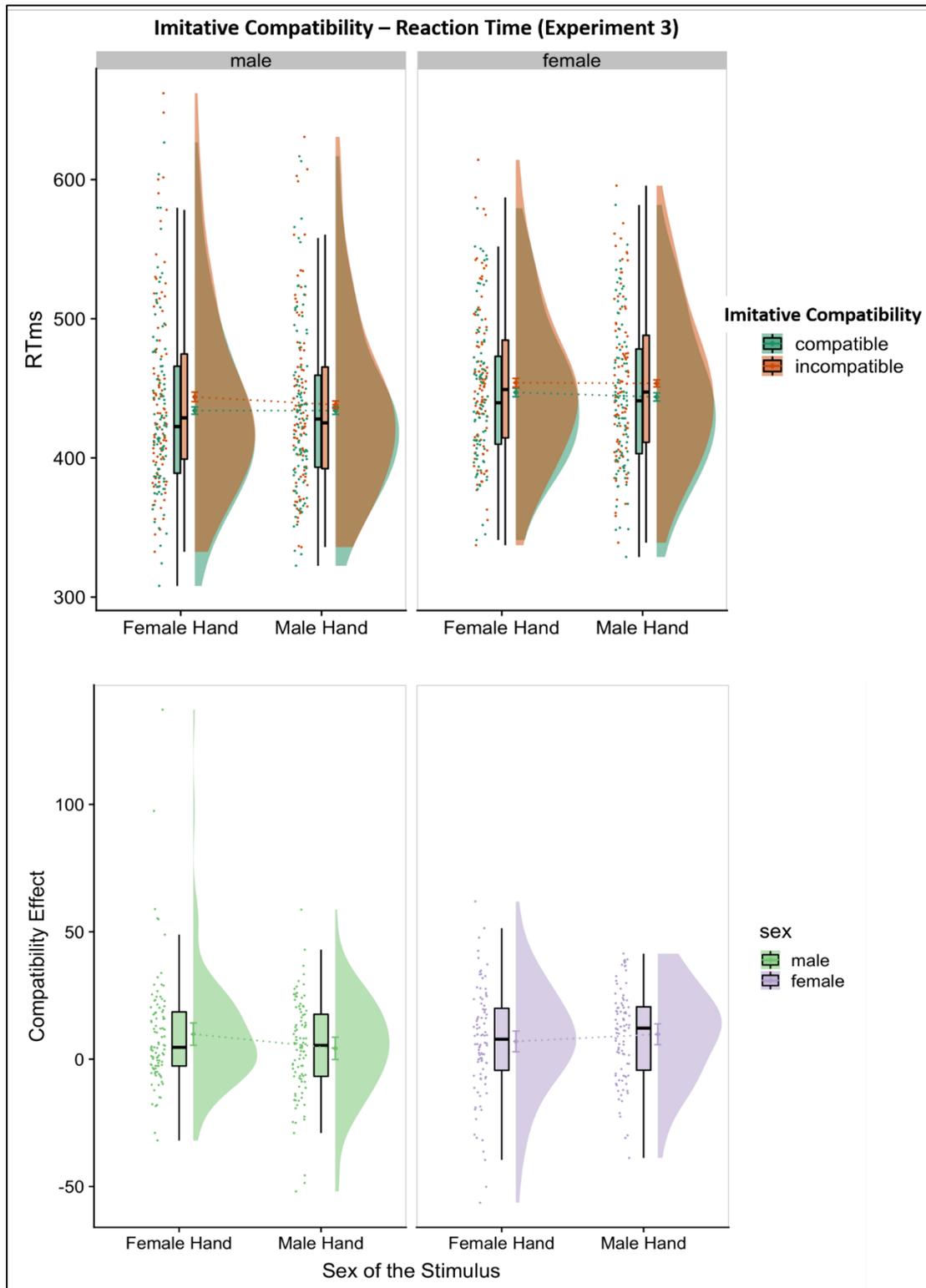
Figure 12. *Experiment 3 – Imitative Compatibility Reaction Time.* Reaction time is reported in milliseconds (ms). The upper panel shows mean reaction times for compatible and incompatible conditions for both males and females when responding to both male and female hand stimuli. The lower panel shows the compatibility effect for both males and females when responding to both male and female hand stimuli. The compatibility effect is calculated by subtracting reaction times on compatible trials from incompatible trials. Error bars represent 95% confidence intervals. Abbreviations: RTms = reaction time in milliseconds.
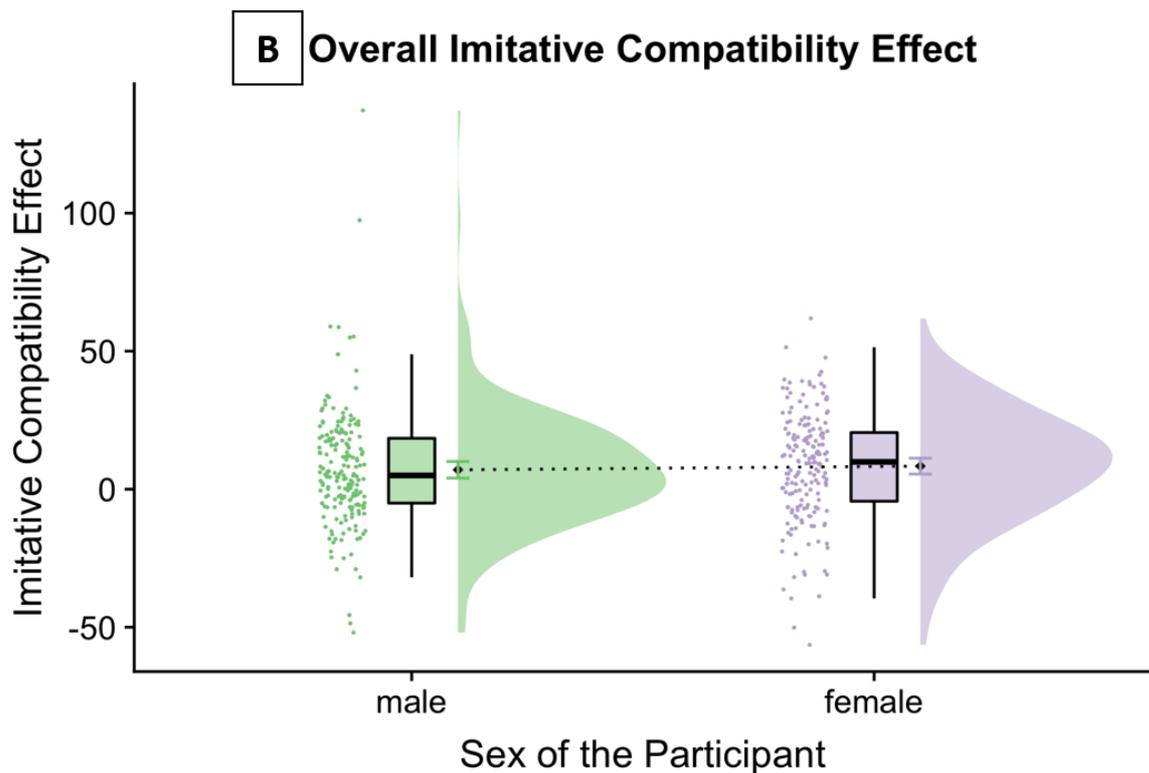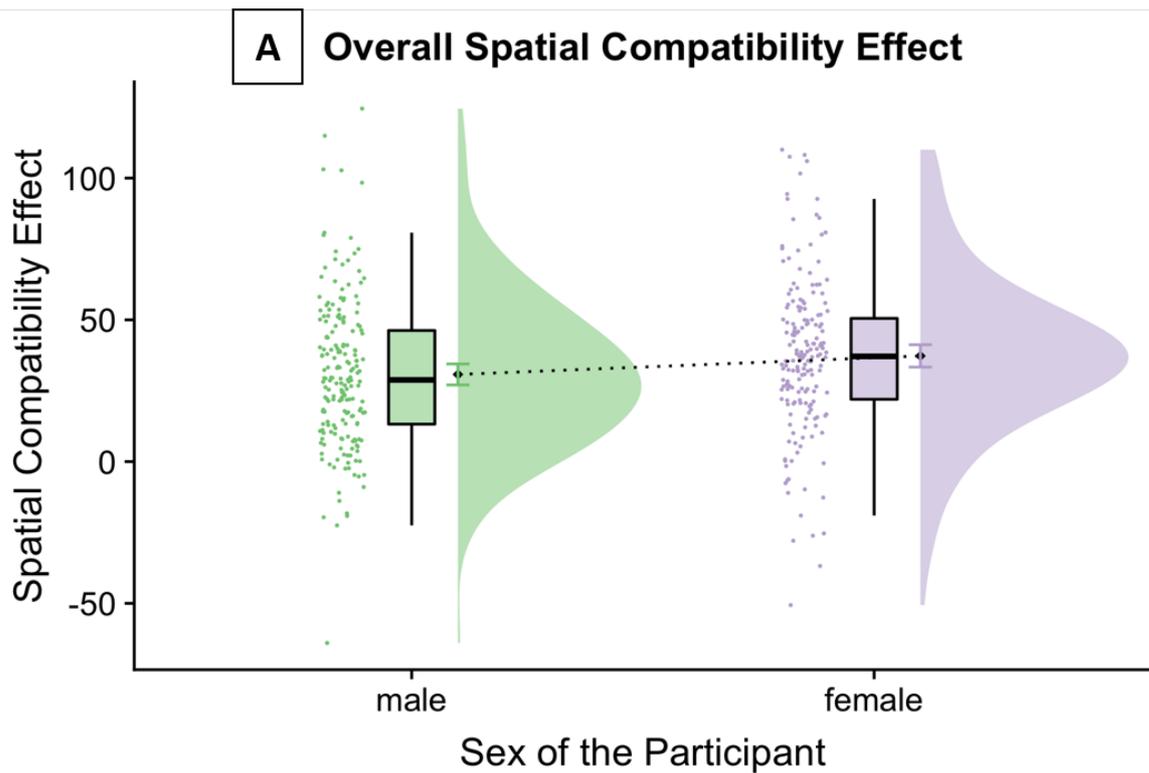
Figure 13. *Experiment 3 – Overall Compatibility Effects.* The upper panel (A) shows the spatial compatibility effect collapsed across sex of the stimulus for both males and females. The lower panel (B) shows the imitative compatibility effect collapsed across sex of the stimulus for both males and females. The compatibility effect is calculated by subtracting reaction times on compatible trials from incompatible trials and is measured in milliseconds. Error bars represent 95% confidence intervals.

Multiple regression analyses

We also investigated the relationship between stable personality measures and the imitative compatibility effect as measured on the SRC task independent of spatial effects. Tests for multicollinearity indicated that a very low level of multicollinearity was present (*VIF* for all predictor variables < 2). The base model (including sex, mean RT and the sex*mean RT interaction) explained 4.59 % of the variance in the imitative compatibility effect (F(3,181)=2.90, p=0.036, R2=.04, f^2=0.05) indicating a small effect. Mean RT was a predictor (B=0.05, SEB=0.02, t(181)=2.79,p=.006, [0.01; 0.09]), but both sex (B=0.23, SEB=1.04, t(181)=0.22,p=.82, [-1.82; 2.29]) and the sex*mean RT interaction (B=-0.003, SEB=0.02, t(181)=-0.21,p=.83, [-0.04; 0.03]) did not predict the imitative compatibility effect (see Figure 14).

When the model included empathy, the model predicted 7.04 % of the variance. Empathic concern predicted the imitative compatibility effect above and beyond the base model (B=-0.51, SEB=0.24, t(179)=-2.08,p=.04, [-0.99; -0.03]), and explained an addition 2.3% of the variance (ΔR2= .023, F(1,179)=4.35, p=.04; Figure 15). A decrease in empathic concern predicted a higher imitative compatibility effect. When agreeableness and extraversion were included in the model, the model predicted 7.09% of the variance. Agreeableness marginally predicted the imitative compatibility effect (B=-2.68, SEB=1.53, t(179)=-1.75,p=.081, [-5.67; 0.33]) and explained an additional 1.6% of the variance (ΔR2= .0016, F(1,179)=3. 07, p=.08). Extraversion also marginally predicted the imitative compatibility effect (B=1.81, SEB=1.09, t(179)=1.67,p=.096, [-0.32; 3.96]) and explained an additional 1.5% of the variance (ΔR2= .015, F(1,179)=2. 78, p=.096). Higher extraversion predicted higher imitative compatibility, whereas higher agreeableness predicted a lower imitative compatibility effect (see Figure 15).

1370   Effect sizes attributable to the addition of empathy (Cohen's f^2 = 0.03), and

1371   agreeableness and extraversion (Cohen's f^2 = 0.03) (beyond the base model) indicated

1372   very small effects.
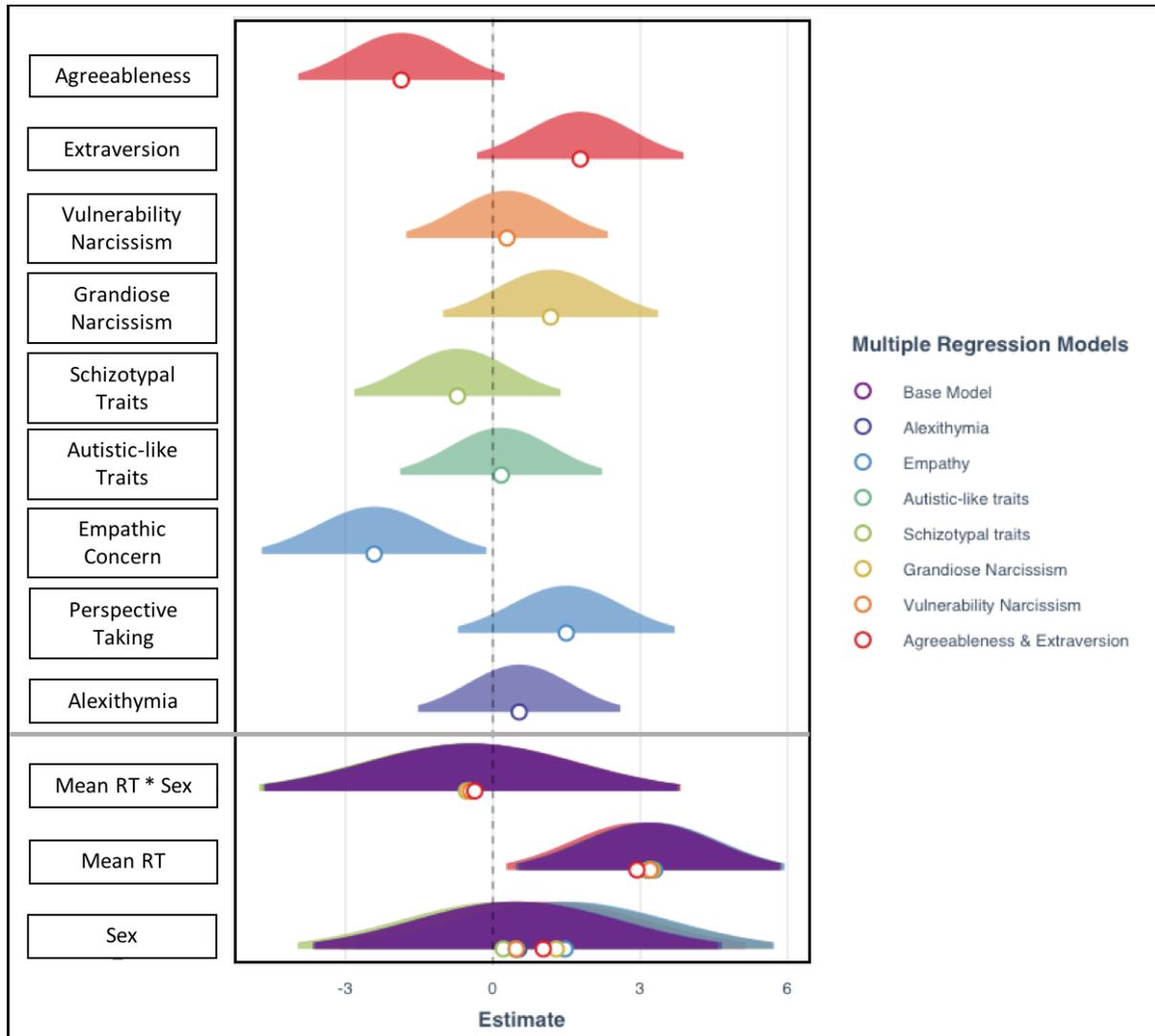

1373

1374   **Figure 14.** *Experiment 3 – Multiple Regression Analyses.* Values of standardised coefficients are
1375   plotted for each predictor variable (personality trait) along with their corresponding
1376   uncertainties (95% confidence interval width for a normal distribution for each estimate).
1377   Coefficients are standardised by dividing by two standard deviation units according to Gelman
1378   (2008). The base model consists in the bottom three predictor variables (depicted in violet) –
1379   mean RT, Sex, and meanRT*Sex. Abbreviations: RT = Reaction Time. *N.B.* The circles on the
1380   purple distributions represent the standardised co-efficients for the main effect of meanRT,
1381   main effect of sex, and meanRT*sex interaction respectively for each of the models tested. That
1382   is why there are multiple circles for components of the base model because the base model was
1383   part of all the models test (that is, one model for each personality trait).

1384

1385   Grandiose and vulnerability narcissism, autistic-like and schizotypal trials, and

1386   alexithymia did not predict the imitative compatibility effect above and beyond the base

1387   model (all p's > 0.3, all CIs overlapping with zero; see Figure 14). The multiple

1388   regression models are summarized in Supplementary Table 13. Zero-order correlations

1389   are also consistent with the findings from the multiple regression analyses (see

1390   Supplementary Table 14, Supplementary Figure 6).
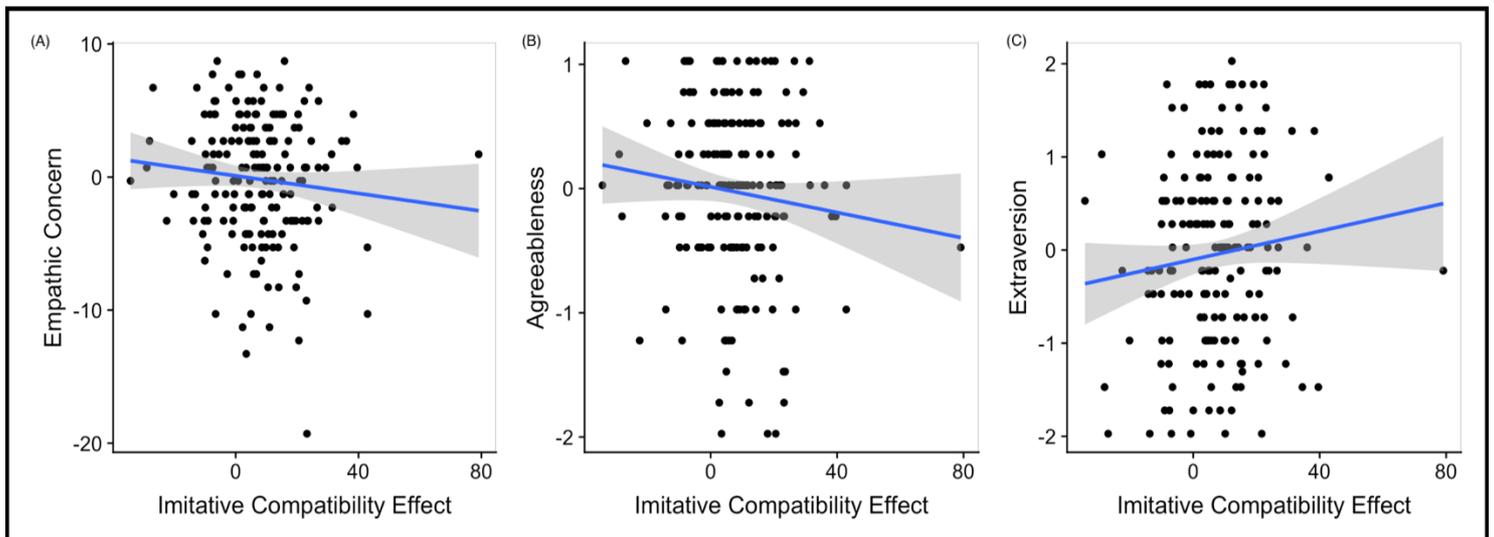
1392   **Figure 15.** *Experiment 3 – Scatterplots.* Scatterplots depicting the relationship between imitative
1393   compatibility effect and personality traits – empathic concern (A), agreeableness (B), and extraversion
1394   (C). X axis denotes the imitative compatibility effect in milliseconds, and Y axis denotes mean centred
1395   scores on the personality traits.

1396

1397   To evaluate the sex*trait interaction terms, we computed additional models –

1398   each model consisted of the base model, one trait predictor (subscales were included in

1399   the same model), and the sex*trait interaction term. None of the sex*trait interaction

1400   terms predicted the compatibility effect above and beyond the base model

1401   (Supplementary Figure 13). Multiple regression models are summarised in

1402   Supplementary Table 15. Effect sizes attributable to the addition of the sex*trait

1403   interaction terms (beyond the base model) indicated very small effects (Cohen's f^2 =

1404   <0.04 for all models). The pattern of results seen in Experiment 1 for the empathy*sex

1405   and alexithymia*sex models did not replicate in Experiment 3 (Figure 6C).

1406   Although our main question of interest was the link between personality traits

1407   and automatic imitation, for completeness, we also report results from the multiple

1408   regression analyses for spatial compatibility in the supplementary material (see

1409   Supplementary Tables 16 and 17, Supplementary Figures 14 and 15).

1410   *Stimuli rating.* All participants also rated the male and female hand stimuli on a

1411   scale of 1 to 9, with 1 being most masculine, and 9 being most feminine. All male hand

1412   stimuli were rated as masculine (Mean rating = 2.93, SD = 0.30). All female stimuli were

1413   rated as relatively feminine (Mean rating = 5.68, SD = 0.65). Although the female stimuli

1414   were not rated as strongly feminine, the ratings suggest that both male and female

1415   stimuli were perceived differently on average by the participants. The stimuli rating

1416   data is also available online.

1417   **Discussion**

1418   Results from Experiment 3 clearly show that a sex difference exists on the

1419   spatial compatibility effect such that females show a higher spatial compatibility effect

1420   than males. This difference did not persist when imitative compatibility was measured

1421   independently. This suggests that females and males do not differ in the control of

1422   automatic imitation as measured by the imitative compatibility effect.

1423   Furthermore, for the first time to date, we manipulated the sex of the stimuli

1424   across both male and female participants. Results indicated that there was no own-sex

1425   bias in the imitative compatibility effect. For the spatial compatibility effect, although

1426   the findings showed a trend toward an own-sex bias such that females showed a greater

1427 compatibility effect on female stimuli than male stimuli, this was a relatively small effect

1428 size, and thus does not explain much of the sex difference observed in the spatial

1429 compatibility effect.

1430   The findings from Experiment 3 thus suggest that it is unlikely that there is a

1431 sex difference in the imitative compatibility effect. Instead, our findings suggest that

1432 there is a sex difference in the spatial compatibility effect, which may reflect a difference

1433 in spatial control between males and females that in the case of this experiment is

1434 triggered by the location of a finger in space.

1435   The multiple regression analyses suggest that the imitative compatibility effect

1436 is invariant to stable traits of personality including grandiose and vulnerability

1437 narcissism, autistic-like and schizotypal traits, as well as alexithymia.

1438   Given prior evidence, we predicted that individuals who report higher empathy,

1439 extraversion, and agreeableness would be more prosocial, and would therefore imitate

1440 more than those who scored lower on these measures. In the current experiment,

1441 although higher extraversion predicted higher imitation, we found the opposite pattern

1442 for empathy and agreeableness. An increase in empathic concern and agreeableness

1443 predicted a decrease in the imitative compatibility effect. The effects, however, were

1444 small and predicted only an additional 2.45% (empathy) and 2.5% (extraversion and

1445 agreeableness) of the variance. Before making any firm conclusions, these results would

1446 need to be replicated using large sample sizes to ensure that these findings do not

1447 reflect false positives. In addition, none of the sex*trait interactions predicted the

1448 imitative compatibility effect, and the pattern of results from Experiment 1 for the

1449 sex*empathy and sex*alexithymia interactions did not replicate over Experiment 2 and

1450 3 (see Figure 6). Overall, therefore, these results provide only limited support for small

1451 or negligible effects of personality on automatic imitation reinforcing the suggestion

1452 that automatic imitation is largely invariant to stable traits of personality (Butler et al.,

1453 2015; Cracco et al., 2018).

1454   For all three experiments, we performed all the analyses again by further

1455 excluding participants who were three standard deviations away from the group mean

1456 on the compatibility effect on either of the tasks. For Experiment 1, no additional

1457 participants were excluded. For both Experiment 2 and 3, one additional participant

1458 was excluded. Obtained results were very similar to those reported above.

1459

1460   **General Discussion**

1461 By integrating methodological approaches from experimental and differential

1462 psychology, the current study shines new light on the relationships between stable

1463 features of individuals, such as personality and sex, and the architecture of cognitive

1464 control systems. Across three experiments, we consistently showed that cognitive

1465 control systems are largely invariant to stable aspects of personality, but exhibit a sex

1466 difference, such that females show greater interference than males. Moreover, we

1467 further qualified this sex difference in two ways. First, we showed that the sex

1468 difference was unrelated to the sex of the interaction partner and therefore did not

1469 reflect an in-group bias based on sex. Second, we showed that the sex difference was

1470 tied to a form of spatial interference control rather than imitative control and therefore

1471 it is unlikely to reflect a specialised mechanism for guiding social interactions

1472 exclusively. Instead, our findings suggest that a robust sex difference exists in the

1473 system (or set of subsystems) that operate in resolving a form of spatial interference

1474   control. The implications of these findings for understanding cognitive control systems

1475   in social and non-social contexts are discussed.

1476   **Are individual differences in interference control robust and replicable?**

1477   In recent years, a key question in psychology and neuroscience has concerned

1478   the credibility of reported findings (Open Science, 2015; Button et al., 2013; Pashler et

1479   al., 2012; Munafo et al., 2017; Vazire, 2018) with estimates of replicability ranging

1480   between 25 and 75% (Nosek & Lakens, 2014; Matzke et al., 2015; Marsman et al., 2017;

1481   Camerer et al., 2018). Studies that integrate experimental and differential approaches

1482   are rare in general, and in the context of imitation control, prior studies have typically

1483   used small sample sizes (Ainley et al., 2014; Chartrand & Bargh, 1999; Hogeveen & Obhi,

1484   2013; Obhi et al., 2013; Santiesteban et al., 2015). As such, one important contribution

1485   from the current study is a more robust and precise estimate of the size and

1486   replicability of sex differences in cognitive control. To do so, we used relatively large

1487   sample sizes, which could detect small-to-medium effect sizes with a high degree of

1488   confidence, and ran three separate experiments using designs that combined

1489   approaches from experimental and differential psychology.

1490   In Experiments 1 and 2, we replicated the sex difference found previously both

1491   when the SRC task measured automatic imitation as a composite of imitative and left-

1492   right spatial effects (Butler et al., 2015), as well as orthogonal spatial compatibility

1493   effects (Genschow et al., 2017). Furthermore, in Experiment 3, we measured imitative

1494   compatibility effects independent of spatial compatibility effects (Catmur & Heyes,

1495   2011; Berthental et al., 2006; Boyer et al., 2012; Jimenez et al., 2012). In Experiment 3,

1496   females showed a greater spatial compatibility effect than males, but there was no

1497   difference between the sexes on imitative compatibility. Thus, it is clear that the sex

73

1498   difference on the SRC task reflects a difference in spatial control between males and

1499   females, rather than a difference in a specialised system that is dedicated to social

1500   control.
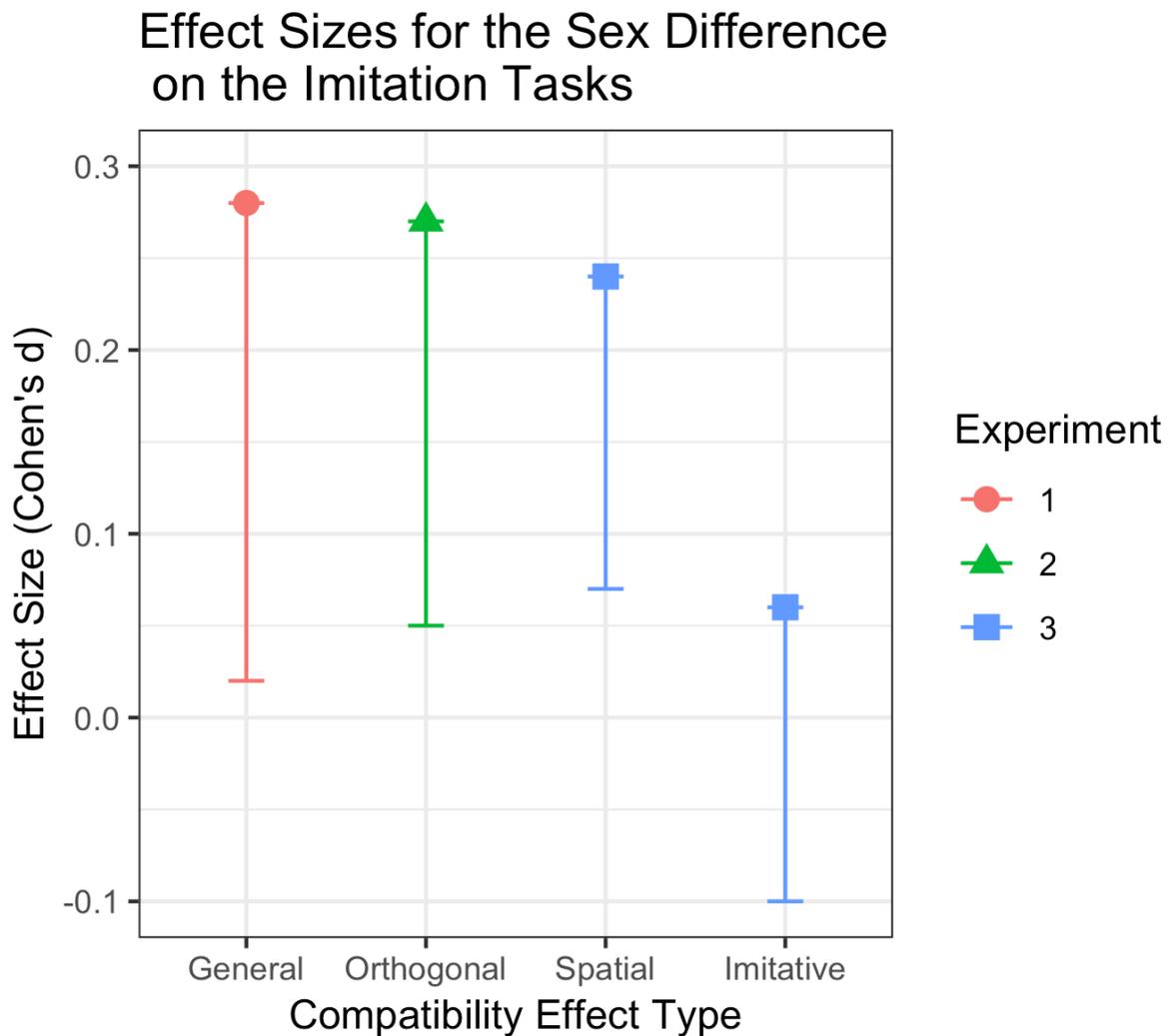
1501
1502   **Figure 16.** *Effect Sizes of the Sex Difference.* Cohen's d effect sizes of the sex difference on the
1503   imitation task (compatibility effect) across Experiments 1, 2, and 3. Error bar denotes one-tailed
1504   95% confidence interval.

1505

1506   According to Cohen's benchmarks for interpreting effect sizes (Cohen, 1992), the

1507   difference between the sexes was a small-to-medium effect size (Cohen's d = 0.28) and

1508   was relatively consistent across the three experiments, with the lower bound of the

1509   95% CI > 0.02 (see Figure 16). Considering the sensitivity of our design, it is important

1510 to note that these effect sizes were below the 80% power mark, which our power

1511 analysis identified, as we had 80% power to detect effects greater than Cohen's d 0.36.

1512 Each individual experiment, therefore, has less than 80% power. This said, all three

1513 experiments showed results similar to Butler and colleagues (2015), in that they were

1514 in the same (predicted) direction and of a consistent magnitude even though the effect

1515 sizes were small. Further, consistent small effect sizes in large-N studies are more likely

1516 to represent the true state of nature than large effect sizes in small-N studies. In

1517 addition, these small effects can cumulate in their importance over time (Funder & Ozer,

1518 2019). By replicating the effects in separate large sample designs, it makes it less likely

1519 that these results represent sampling error (Zwaan et al., 2018). If we interpret the

1520 length of confidence interval (Armhein et al., 2019; Cumming, 2012), then our best

1521 estimate is a small to medium effect, with all likely effects being in the predicted

1522 direction (i.e., greater than zero). Therefore, building on prior work (Butler et al., 2015),

1523 across three large-sample experiments, we have provided a robust and relatively

1524 precise estimate of the size of the sex difference and shown that it reflects spatial rather

1525 than social control mechanisms.

1526   Moreover, across all three experiments, we consistently found that the control of

1527 automatic imitative tendencies, as measured by the SRC task, is invariant to differences

1528 in personality traits across individuals. Recently, it has been suggested that the

1529 investigation of an experimental effect at the group level, and individual differences

1530 within that effect are questions that can be at odds with each other. This is because

1531 group effects need low variability within the sample whereas differential psychology

1532 questions are dependent on high variability within the sample (Rogossa, 1988).

1533 Therefore, we cannot assume that robust experimental paradigms such as the SRC tasks

1534 used in the current experiments will lend themselves well to individual difference

1535 approaches. Thus, although a difference between groups can be detected if the groups

1536 means are sufficiently far away from each other to be detectable, the tasks used may not

1537 be able to distinguish between individuals in the population consistently (Hedge et al.,

1538 2017).

1539 Compared to prior studies (Obhi et al., 2013; Obhi & Hogeveen, 2013; Chartrand

1540 & Bargh, 1999), however, we provide a more robust test of hypotheses regarding

1541 individual differences as we used larger sample sizes, which produce higher statistical

1542 power, and we looked for consistent patterns of data across multiple experiments. By

1543 doing so, a more stable picture is emerging with regard to personality and SRC

1544 measures of automatic imitation, which suggests that mechanisms of imitative control

1545 are largely invariant to dimensions of personality (Butler et al., 2015; Genschow et al.,

1546 2017; Cracco et al., 2018), even when they are operating in more socially rich contexts

1547 (Exp. 1) and when spatial and imitative effects are more clearly separated (Exps. 2 and

1548 3). In short, any effects of personality were small and inconsistent across experiments.

1549 Of course, our design did not have sufficient power to detect small effects with

1550 reasonable confidence (> 80%), and such effects would require considerably larger

1551 sample sizes to be able to confidently confirm that they exist. Thus, our best estimate at

1552 present is that the effects of personality on SRC measures of automatic imitation are

1553 negligible or small.

1554 **Do differences in cognitive control reflect a sex difference or an in-group bias?**

1555 In Experiments 1 and 2, as well as in prior studies that have observed sex

1556 differences in the SRC imitation task (Butler et al., 2015; Genschow et al., 2017), the

1557 stimuli used were of a female hand. Thus, it was possible that the sex difference

1558 reflected an in-group bias leading to higher compatibility effects for females compared

1559 to males (Cracco et al., 2018). Indeed, there is already suggestive evidence (from studies

1560 with relatively small sample sizes), that both facial imitation and SRC measures of

1561 imitation have been found to increase when the interacting partner is an in-group

1562 member compared to an out-group member based on race, ethnicity, and arbitrary

1563 group assignment (Mondillon et al., 2007; Rauchbauer et al., 2015; Gleibs et al., 2016).

1564   In the current study, based on the sex of the interaction partner, we show no

1565 clear evidence for an own-sex bias for either spatial or imitative compatibility.

1566 Moreover, in terms of sensitivity, the use of a larger sample size than is typical means

1567 that our study had 80% power to detect effect sizes at or above Cohen's d = 0.36, which

1568 means that we can be reasonably confident that effect sizes of this magnitude or larger

1569 are unlikely. Taken together, although ingroup biases are potent in everyday life and

1570 relate to sex, race and ethnicity (Brown, 1995; Yee & Brown, 1995; Fischbein, 1996,

1571 Powlishta, 1995; Rudman & Goodwin, 2004; Kubota et al., 2012; Malpass & Kravitz,

1572 1969), the difference in interference control reported here reflects the sex of the

1573 participant, rather than an in-group bias based on the sex of the interaction partner. As

1574 such, these results are contrary to proposals put forward by Cracco and colleagues

1575 (2018), and highlight a stable individual difference in interference control, rather than

1576 an effect of the social context (i.e., the sex of the interaction partner).

1577 **What type of cognitive system underpins sex differences in interference control?**

1578   Three broad structures of cognitive system were candidates to underpin the sex

1579 difference in interference control: 1) a sex difference specific to social imitative control;

1580 2) a sex difference generalised across all types of control; 3) a sex difference specific to

1581 a form of non-social control. If the sex difference was solely tied to imitative control and

1582 reflected the workings of a specialised and domain-specific cognitive structure, we

1583 would have observed a sex difference only on the imitative compatibility component of

1584 the task. Likewise, if the sex difference reflected the operation of a straightforwardly

1585 domain-general system, we would have expected a difference between males and

1586 females on the flanker task, as well as both the spatial and imitative components of the

1587 automatic imitation SRC task. As such, these findings demonstrate that the sex

1588 difference is neither completely domain-general i.e., it does not generalise across all

1589 types of compatibility effects nor is it domain-specific i.e., it is not solely tied to the

1590 control of automatic imitation.

1591   Our findings show more support for the third type of cognitive system outlined

1592 above, which suggests that the sex difference reflects a particular type of non-social

1593 interference, which is not shared across all SRC tasks. Indeed, across our experiments,

1594 the sex difference was tied to a type of spatial interference observed in the spatial

1595 component of the automatic imitation SRC task, but not the imitative component of the

1596 same task or the non-social flanker task. A sex difference on spatial control, but not on

1597 imitative control, when measured on the same task, suggests that although general

1598 cognitive control systems are engaged for both tasks to some extent, they may not be

1599 engaged in an identical manner across both the compatibility effects. Moreover, it is

1600 unlikely that the sex difference on spatial compatibility reflects a difference in the

1601 perceptual processing of the social stimulus (i.e. the hand on the screen) as the stimuli

1602 are the same across both compatibility effects, but no sex difference emerges on the

1603 imitative compatibility effect. For both imitative and spatial compatibility, therefore, the

1604 input to the control mechanism that resolves conflict is the same i.e. a finger. However,

1605 the way conflict is resolved for spatial and imitative effects might involve mechanisms

1606 that operate differently as a function of sex.

In addition to the sex difference not being tied to social or imitative control, it also reflects a component that is not shared with the flanker task. A lack of sex difference on the flanker task, and little or no correlation between the compatibility effects on the two tasks, has at least two possible interpretations, which are not mutually exclusive. First, it could reflect a lack of sensitivity. The differences between females and males on behavioural indices (such as RT) on the flanker task may be small (Clayson et al., 2011; Fischer et al., 2015; Stoet, 2011). In the current experiment, our sensitivity analysis suggests that we could detect effect sizes of Cohen's d > 0.36 with reasonable confidence (80%), but the effects of sex on the flanker were smaller than this in Experiment 1 and 2 (Cohen's d = 0.15 and 0.03, respectively). Moreover, a large sample study with 895 participants found a small sex difference in the predicted direction on the flanker task using arrows such that females showed a greater compatibility effects than males (Fischer et al., 2015). Thus, there could also be a non-zero sex difference on the flanker task, but even if this turns out to be the case, it is clear that the size of the sex difference varies across different types of non-social cognitive control tasks.

A second possible reason for the lack of sex difference on the flanker task is that the sex difference is underpinned by a particular type of non-social control. Previous studies help contextualise this finding by showing that females differ from males across a wide range of cognitive control tasks, especially those involving spatial processing (Bayliss & Tipper, 2005; Clayson et al., 2011; Stoet et al., 2017; Stoet, 2011). One possibility, therefore, is that the sex difference may reflect a difference in the two types of spatial conflict measured by the flanker and spatial compatibility effect. For example, in the SRC task measuring spatial compatibility, the conflict arises because a stimulus feature is inconsistent to the response, whereas the flanker task measures both

1632 stimulus-stimulus and stimulus-response conflicts (Kornblum et al., 1990; Kornblum,

1633 1994; Verbruggen et al., 2006). Further, it has been proposed that stimulus-response (S-

1634 R) conflicts and stimulus-stimulus (S-S) conflicts are underpinned by different

1635 processing patterns (Kornblum & Lee, 1995; Kornblum et al., 1999; Kornblum et al.,

1636 1990; Li et al., 2014; Frühholz et al., 2011; Zhang et al., 1999). Therefore, these types of

1637 conflicts would be worth taking into consideration in future research that investigates

1638 individual differences in automatic imitation, and social and non-social cognitive

1639 control.

1640   More generally, other sex differences, which do not rely on SRC paradigms, can

1641 further contextualise our findings. Indeed, prior research suggests that females differ

1642 from males on a range of social processes (Baron-Cohen, 2002). For example, females

1643 show greater empathy than males, which may lead to more pro-social behaviour, thus

1644 suggesting that females may imitate more than males (Christov-Moore et al., 2014;

1645 Baron-Cohen & Wheelwright, 2004; Schulte-Rüther et al., 2008). However, although

1646 empathy has been associated with a variety of paradigms investigating automatic

1647 imitation (Mueller et al., 2013; Sonnyby-Borgstrom 2002; Chartrand & Bargh, 1999),

1648 there does not seem to be a clear link between empathy and automatic imitation as

1649 measured on the SRC task (Butler et al., 2015; Genschow et al., 2017). Moreover, while

1650 females show higher facial mimicry than males (Sonnby-Borgstrom 2002; 2008;

1651 Dimber, 1990; Hess & Bourgeois, 2010; Korb et al., 2015; Lundqvist, 1995), studies

1652 investigating imitation of other behaviours, such as nose-scratching, have not found any

1653 reliable sex differences, although such studies have been limited by small sample sizes

1654 (Chartrand & Bargh, 1999). Inconsistent and equivocal results across imitation tasks

1655 might suggest that these tasks engage different cognitive mechanisms.

1656   In addition, while we separated the spatial and imitative effects in Experiment 3

1657   using a modified version of the paradigm developed by Catmur and Heyes (2011), there

1658   are other tasks that measure imitative effects not confounded with spatial compatibility

1659   effects (e.g. Bortoletto et al., 2013). Thus, any conclusions we make our limited to the

1660   type of task we used in the current experiment. However, whether other tasks are more

1661   powerful measures of imitative effects is an empirical question that would need to be

1662   tested by future research.

1663   These findings raise a fundamental issue that remains unresolved does the SRC

1664   task actually link to imitation "in the wild" and social cognition more broadly. The

1665   domain of social cognition research has seen the use of cognitive psychology paradigms

1666   and methodologies to answer questions that are of interest to social psychologists

1667   (Lambert & Scherer, 2013). But are these paradigms truly measuring what we think

1668   they are measuring? More and more recent evidence suggests that social cognition is

1669   fundamentally different when we are involved in live social interactions with each other

1670   as compared to when we are doing tasks in a controlled environment (Schillbach et al.,

1671   2013; Redcay & Schillbach, 2019). For instance, researchers have suggested that eye-

1672   gaze behaviours when measured using screen-based tasks cannot be validly generalised

1673   to and used as a proxy for understanding gaze behaviours in live social interaction

1674   settings (Grossman, Zane, Mertens, & Mitchell, 2019). Thus, more empirical evidence is

1675   needed to know whether the SRC task of automatic imitation is actually measuring a

1676   social cognitive process (or just one component of a multi-dimensional construct like

1677   imitation).

1678   Indeed, although different measures of automatic imitation have been previously

1679   assumed to rely on the same underlying mechanisms, there is accumulating empirical

1680   and theoretical reason to question such an assumption (Ramsey, 2018; Genschow et al.,

1681 2017). Thus, divergent sex differences across measures of different dimensions of

1682 automatic imitative behaviour may reflect differences in cognitive mechanisms that

1683 underpin these tasks.

1684

1685 **Limitations/ Constraints on generality**

1686   In the current work, we make conclusions about social and non-social cognitive

1687 control on the basis of compatibility effects measured on flanker and imitation tasks.

1688 This makes sense because we had predictions specifically about individual differences

1689 in social and non-social cognitive control as measured by compatibility effects.

1690 However, there are many processes that contribute to such compatibility effects, and

1691 cognitive control is only one of them. Therefore, we cannot be sure that individual

1692 differences (or lack thereof) on these tasks are tied to individual differences in cognitive

1693 control (Musslick et al., 2019). Thus, an important and complementary direction for

1694 future research would be to disentangle the extent to which inter-individual differences

1695 reflect differences in cognitive control or other cognitive capacities. To do so, one may

1696 include a baseline condition for both the flanker and imitation tasks, which may help to

1697 separate differences in cognitive control from differences in other factors that also

1698 contribute to SRC tasks.

1699   A second potential limitation to the current work is the use of the flanker task as

1700 a measure of non-social cognitive control. Cognitive control has various components

1701 which can be measured by many different tasks (Rondeel et al., 2015). However, we use

1702 different non-social tasks across the three experiments (i.e. flanker in Experiments 1

1703 and 2, and spatial compatibility in Experiment 3) as a comparison with the automatic

1704 imitation task and find similar results irrespective of the type of task we used.

1705 Therefore, although every task has drawbacks, we feel that our key findings are

1706 relatively robust in the sense that they remain largely indifferent to changes in

1707 experimental design.

1708

1709 **Conclusion**

1710 The current findings provide a general insight into the relationship between individual

1711 differences and cognitive control systems in social and non-social contexts. Integrating

1712 experimental and differential psychology approaches, across three large sample

1713 experiments, we show that there is negligible or no evidence for a link between social

1714 control and stable personality traits. However, cognitive control systems vary as a

1715 function of biological sex, such that females show a greater interference than males.

1716 Further, this sex difference does not reflect an in-group bias based on the sex of the

1717 interacting partner, and is not tied specifically to social control but reflects differences

1718 in the cognitive systems that operate in resolving a form of spatial interference.

1719 Therefore, we show that the sex difference exists in the system (or set of subsystems)

1720 that operate in resolving a form of spatial interference control, and that such systems

1721 are unaffected by social factors such as facial expression or the sex of the interaction

1722 partner. More generally, the results highlight the value of integrating approaches from

1723 experimental and differential psychology, as well as using large sample sizes, in order to

1724 investigate the relationship between cognitive control architectures and stable traits of

1725 individuals, which few studies have achieved to date.

1726

1727

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