SEX DIFFERENCES ON THE GO/NO-GO TEST OF INHIBITION

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ABSTRACT

Parental investment theory suggests that women, due to greater investment in child rearing, can be more choosy than men when considering a potential mate. A corollary to this is that women should possess greater inhibition abilities compared to men in contexts related to sex and reproduction. This notion has found support from the inhibition literature demonstrating that while women do indeed show greater inhibition on tasks that include a social aspect, no such effect is found on cognitive tasks that do not possess a social component. In the present experiment, participants (*N* = 66) performed a variant of a classic Go/No-Go task consisting of infrequent No-Go trials in which a response needed to be withheld. Importantly, the stimuli were geometric shapes possessing no social component. Results showed that women outperformed men on the No-Go trials, indicating greater inhibition. No significant difference was found in reaction time on Go trials. Thus, the results cannot be explained in terms of a speed/accuracy trade-off. We discuss the findings in the context of the female-evolved inhibition hypothesis.

Keywords: Go/No-Go task; Stop-Signal; inhibition; sex difference, reaction time

INTRODUCTION

One of the central tenets of evolutionary psychology concerns sex differences with respect to investment in child rearing. Specifically, relative to males, females tend to invest more in offspring. These differences are associated with the fact that whereas females are limited in the total number of offspring they can bear, males are not. This limitation is primarily due to the lengthy gestation period undergone by the female as well as greater post-birth care in the form of lactation. An important consequence of this asymmetry is that females, relative to males, can be very selective when choosing a potential partner (Janetos, 1980; Trivers, 1972) and an abundance of evidence supports this notion (e.g., Baranowski & Hecht, 2015; Buss & Schmitt, 1993; Clark & Hatfield, 1989; Gueguen, 2011).

The corollary to this is that there is potentially greater cost to females in choosing an unsuitable partner. In this context, Bjorklund and Kipp (1996) proposed that women have evolved inhibitory mechanisms partly because they need to inhibit certain behaviors more effectively than men, especially behaviors concerned with choosing a partner. Men on the other hand are less discriminate in their mating strategies and no such inhibition mechanism is likely to have evolved (Buss & Schmitt, 1993). This view of female inhibition followed the general theory put forward by Bjorklund and Harnishfeger (1995), who posited that human inhibitory mechanisms and processes evolved partly in order to regulate social and emotional responses concerned with cooperation and/or individual success. For example, withholding information, particularly concerning one’s real feelings and attitudes, can be seen as an important skill. In applying this theory within a reproductive strategy framework, Bjorklund and Kipp argued that women should be expected to have greater control of their sexual arousal and be better able to hide interest in a male. Bjorklund and Kipp were therefore suggesting a domain-specific view of inhibition in which inhibitory processes are said to have evolved to deal with specific issues and problems. This contrasts the domain-general view in which inhibition is considered to have evolved in order to tackle a whole range of broad problems where inhibition of certain behaviors would be useful. Indeed, a necessary condition of the female-evolved inhibition theory is that inhibition mechanisms and processes should not be domain-general.

Evidence for the domain-specific view of human inhibition comes from the literature demonstrating the relative independence of different inhibition abilities. For example, the various tasks that index different categories of inhibition do not correlate well, if at all. Noreen and MacLeod (2015) found no significant relationship between performance on a memory stopping paradigm (the Think/No-Think paradigm), in which the recall of certain stimuli needs to be prevented, and performance on a standard Go/No-Go behavioral inhibition task (see below). Furthermore, Noreen and MacLeod additionally found that the extent of forgetting on this memory inhibitory task was not reflected in the level of forgetting observed on another memory inhibitory task (the Impossible Retrieval task). This led Noreen and MacLeod to conclude that “our findings could be taken as a challenge to the notion of a single inhibitory mechanism” (p 14). Furthermore, Imhoff and Schmidt (2014) showed that disinhibition induced by listening to erotic stimuli was specific to responses concerning sexual behavior. In an extensive review, Nigg (2000) outlined eight different types of inhibition, including interference control (e.g., Stroop), motivational (e.g., response to punishment and novelty), oculomotor (i.e., suppression of reflective saccades), and automatic orienting of attention. Nigg supported these distinctions with reference to the separate neural structures associated with each. For instance, inhibition of a recently attended region of the visual field is linked to activity in the superior colliculus (Dorris, Klein, Everling, & Munoz, 2002), and response to novelty is linked with the amygdaloid structure (Wright, et al. 2003).

The most obvious precondition of the female-evolved inhibition theory is the demonstration that sex differences occur on tasks that include some form of inhibitory component, particularly tasks in which sexual stimuli are presented. A number of studies do report that females show greater inhibition of sexual response. For instance, Carpenter, Janssen, Graham, Vorst, and Wicherts (2008) found that women score higher on the items that index inhibition on the sexual inhibition/sexual excitation scales (Janssen, Vorst, Finn, & Bancroft, 2002). Relatedly, the female-evolved inhibition hypothesis predicts that females should show greater inhibition on a variety of tasks concerning social processing. In their review, Bjorklund and Kipp (1996) classified inhibition tasks into three categories: social, behavioral, and cognitive. A task was considered social if it concerned a social interaction or relationship, behavioral if it concerned resistance to temptation and gratification, and cognitive if it concerned the blocking of cognitive content or processes. The central finding was that in every social task women demonstrated greater inhibition than men. This contrasted with the behavioral tasks, which demonstrated a less robust female effect and, most importantly, the cognitive tasks which showed no reliable effects. Indeed, Bjorklund and Kipp reported that some visual cognition tasks requiring the suppression of unwanted stimuli showed greater male inhibition. This is supported by more recent evidence showing that males are better at suppressing distracting flankers that surround a target (Stoet, 2010). However, other studies do report a female advantage in tasks involving more general cognitive inhibition, such as the Wisconsin Card Sorting Task (Paniak, Miller, Murphy, & Patterson, 1996), thought suppression (Rassin, 2003), and the Stroop task (Golden, 1974; Peretti, 1969; Sarmany, 1977).

The Go/No-Go and related Stop-Signal task have become two of the main paradigms employed to examine response inhibition. The tasks have been particularly useful in examining inhibitory processes in neurological patients and individuals with Attention Deficit Hyperactivity Disorder (ADHD, e.g., Yong-Liang et al., 2000). In the basic Go/No-Go procedure, participants are asked to make rapid responses to frequently presented stimuli and withhold responses to certain infrequent stimuli (Lapping & Eriksen, 1966; Logan, 1994). The Stop-Signal paradigm is identical with the exception that a Go signal is followed by a Stop-Signal. Thus, in the latter, a response preparation needs to be cancelled (for review, see Verbruggen & Logan, 2008). Successful inhibition is associated with a number of factors, including the frequency of Stop and No-Go trials. For instance, a lower frequency of Stop trials will produce faster responses on Go trials, and the likelihood of inhibition is reduced (Ramautar, Kok, & Ridderinkhof, 2004). Inhibition is also associated with the ability to successfully switch attention from the Go cue to the Stop cue (Bekker, Kenemans, Hoeksma, Talsma, & Verbaten, 2005).

Despite the ubiquitous nature of the Go/No-Go and Stop-Signal paradigms, only a small number of studies have reported data on sex differences. Indeed, the effect of sex has largely been overlooked, and when it is included as a variable of interest it is usually on patients with a psychiatric disorder such as ADHD (Wright, Lipszyc, Dupuis, Thayapararajah, & Schachar, 2014). Those studies that have included sex as a variable found no significant difference in performance. For instance, Macapagal, Janssen, Fridberg, Finn, and Heiman (2011) examined a number of factors potentially associated with Go/No-Go performance (e.g., impulsivity), including sex, and found no overall significant difference (see also Erickson et al., 2005; Li, Huang, Constable, & Sinha, 2006, 2009; Mulvihill, Skilling, & Vogel-Sprott, 1997; Thakkar et al., 2014). Macapagal et al. did, however, find that women made more false positives on images that included sexual content. A recent meta-analysis on the Go/No-Go task found that sex did not significantly moderate response inhibition in patients with ADHD and other psychiatric disorders (Wright et al., 2014), though this was not investigated in healthy participants. A meta-analysis of the Stop-Signal task and ADHD found the same pattern of data (Lipszyc & Schachar, 2010). In the studies on healthy participants where effect size calculation was possible, all were found to be small or very small (a positive *d* refers to a female advantage): $d = 0.04$ (Li et al., 2006), $d = 0.11$ (Thakkar et al., 2014), and $d = 0.28$ (Li et al., 2009).

In addition to these behavioral data, a small number of functional imaging studies have examined sex differences in the activation of brain areas known to be associated with inhibition. For instance, Roberts, Newell, Simoes-Franklin, and Garavan (2008) found that women in the follicular phase of the menstrual cycle showed increased activation in a number of frontal regions (e.g., inferior frontal gyrus) in response to male stimuli. Furthermore, this increased activation was highly correlated with decreased sexual desire and risk taking. This may suggest that when women are especially susceptible to pregnancy their inhibitory processes increase, but only towards male stimuli. However, in direct contradiction to these findings, Colzato, Hertsig, van den Wildenberg, and Hommel (2010) found that women in the follicular phase performed worse than men on Stop trials, and also worse than women in other menstrual phases. It should be noted, however, that the stimuli used in the two tasks were not directly comparable: Roberts et al. used pictures of men and women in a Go/No-Go task, while Colzato et al. used red and green arrows in a Stop-Signal task.

In the present experiment, we assessed the female-evolved inhibition hypothesis by examining the relative degree to which males and females were able to inhibit a response on a variant of the Go/No-Go paradigm. The Go stimuli were one of four possible geometric shapes (square, circle, triangle, and diamond), which were sometimes accompanied by an X to indicate a No-Go trial. The most stringent form of the female-evolved inhibition hypothesis predicts no sex difference in performance because the stimuli do not possess any social component. A more liberal version of the hypothesis posits that evolved female inhibition will generalize to include performance on general cognition tasks.

METHOD

Participants

There were 66 participants (33 female). The mean age was 24.2 years for males and 25.6 years for females, and the sample can be considered homogenous, $t(64) = 1.42$, $p = .16$. Of this sample, 36% were of Norwegian nationality, 27% were British, 3% were Chinese, 3% were Indian, and the remaining 31% were from various nationalities. Participants were recruited via poster advertisements placed at the University of Essex campus, as well as a post on the first author's research page. Recruited participants were given a link to the experiment online and instructed to perform it alone in a quiet room.

Measures

A trial consisted of either a square, rectangle, circle, or diamond, each measuring approximately 5 cm in width, and presented for 2000 ms. These were all blue, presented in the center of the display, against a white background, and acted as the Go stimulus. A No-Go trial was identical with the exception that an X was presented immediately adjacent to the shape, to either the right or the left. A fixation cross was also present between trials. The experiment was presented on the participant's private computer, and SuperCard 4.5 was used as the programming platform.

Procedure

Sex was the between-participant variable. The dependent measure was reaction time for the Go trials, and the number of No-Go trials without a response. A total of 100 trials were presented (in a randomized order): 80 Go, and 20 No-Go. There were also eight practice trials, six Go and two No-Go. Participants received instructions asking them to rest their preferred finger on the "B" button on the keyboard and press it when one of the Go stimuli appeared and withhold a response when an X accompanied the stimulus. They were told to be as fast and as accurate as possible. A response slower than 1000 ms would display the message "too slow" and if there was no response the message "You failed to respond" appeared. If the participant responded within 1000 ms, the message "well done" was shown.

For a No-Go trial, the message “well done” appeared if no response was given within 2000 ms, and the message “incorrect” if the participant pressed the button at any time. The experiment was approved by the University of Essex Psychology ethics committee.

RESULTS

Data from one female participant were discarded because the number of successful No-Go trials was more than four SDs below the mean. Mean reaction times are summarized for men and women in Table 1, along with the mean number of trials successfully inhibited.

With respect to Go trials, failure to respond was rare (1.93%) and there was no significantly different sex effect, $t(63) = 1.54$, $p = .13$, $d = 0.38$. There was also no sex difference in terms of response time, $t(63) < 1$, $d = 0.08$. With respect to No-Go trials, women were more successful in withholding a response, $t(63) = 2.53$, $p < .02$, $d = 0.63$. Overall, these data suggest that women were able to inhibit an action more effectively, and that this was not due to a speed/accuracy trade-off because men and women did not significantly differ in reaction time on Go trials. A power analysis of this result yielded $\delta = 2.54$, indicating a power of .72 (a sample size of $n = 40$ would be needed for each group to achieve a power of .80).

Visual Field Analysis

Alexander, Packard, and Peterson (2002) found that women responded to objects located in the right visual field more quickly than men. They proposed that women may have superior processing of categorical spatial information in the brain’s left hemisphere and are, therefore, faster at processing stimuli that appear in the right visual hemispace. The female advantage observed in the current experiment could therefore be due to superior performance by women in No-Go trials that has the stopping cue to the right. No-Go frequencies (i.e., withholding a response) were therefore additionally analyzed according to the location of the No-Go stimulus. A 2 x 2 mixed ANOVA, with sex as the between-participant variable and location (left/right) as the within-participant variable, found a significant main effect of visual field, $F(1, 63) = 4.09$, $p < .05$, $\eta_p^2 = .06$, and a main effect of sex, $F(1, 63) = 6.38$, $p < .02$, $\eta_p^2 = .01$. Importantly, there was no significant interaction, $F(1, 63) < 1$, $\eta_p^2 = .001$.

DISCUSSION

The female-evolved inhibition hypothesis suggests that women have evolved inhibitory mechanisms in order to inhibit certain behaviors concerned with choosing potentially unsuitable partners. This notion is supported by an abundance of work showing that women, compared to men, demonstrate relatively greater performance on tasks requiring inhibition. Importantly, this female advantage is most prevalent on tasks that include a social component (Bjorklund & Kipp, 1996). Such an advantage is not reliably found on cognitive tasks such as memory interference. In the present work, we employed a classic cognitive psychology paradigm in which participants were required to occasionally withhold a button pressing response. Results showed that women were better at suppressing this simple action. That is, they showed greater inhibition.

We put forward (see Introduction) what could be called the most stringent version of the female-evolved inhibition hypothesis: women should only demonstrate greater inhibition on tasks that include a reproduction/mating component or at the least a social component. We, however, found greater inhibitory control in women despite the fact that the inducing stimuli had no social aspect. This appears to challenge the strictest version of the female inhibition hypothesis. A more liberal version of the hypothesis posits that the current findings would support a somewhat revised theory which suggests that female-evolved inhibition generalizes to other tasks beyond those concerned solely with the processing of social information. Indeed, generalization of a phenomenon is one of the central tenets of evolutionary psychology. This can be seen in, for instance, Lorenz' (1943) notion of *Kindchenschema* (baby schema); a number of key features (e.g., large eyes positioned low in the head) possessed by young infants that often induce a positive feeling in adult humans. This principle, thought to aid the caregiving response, generalizes beyond infant faces. Thus, many non-human animals (e.g., seal) are said to possess the baby schema and can induce a similar positive response (Borgi, Cogliati-Dezza, Brelsford, Meints, & Cirulli, 2014).

The present results could also support a different evolutionary-based account of female behavior. The hunter-gatherer hypothesis (Silverman & Eals, 1992) attempts to explain a number of well-established sex differences. For example, whereas males show superiority in way finding (Voyer, Voyer & Bryden, 1995), females show superiority in object location memory (Eals & Silveman, 1994) and local navigation (New, Krasnow, Truxaw, & Gaulin, 2007). The hunter-gatherer theory posits that such sex differences have arisen as a result of nature selecting skills associated with the division of labor that is thought to have existed during the Pleistocene period. Specifically, selection would have favored females with skills associated with gathering (e.g., small scale navigation, object recognition, and recall) and males with skills associated with hunting (e.g., large scale navigation). Furthermore, one would expect Darwinian selection of hunter-gatherer abilities to have acted upon visual cognition abilities. In this context, Stoet (2010) employed the flanker paradigm to examine the relative ability of males and females in being able to process peripheral information. In the basic flanker task (Eriksen & Eriksen, 1974), participants are asked to discriminate a centrally located target letter that is flanked by distracting letters. Stoet suggested that women should be more distracted by these because their gathering past required them to be more open to peripheral information. Stoet found that females were indeed more sensitive to the presence of flanking stimuli. In the current experiment, a flanking stimulus was also present on No-Go trials. It is possible, therefore, that the female advantage was due to our female participants processing the No-Go stimulus more effectively, resulting in the behavioral difference we observed. This alternative account necessarily suggests that inhibitory mechanisms, evolved or otherwise, were not primarily responsible for the current sex difference. Of course, the presently employed paradigm, in which the No-Go stimulus was presented peripherally, cannot reveal the speed with which flanker information was processed because the task necessarily required participants to withhold a response.

The flanker component of the present experiment could also explain why we observed greater inhibition in women, compared with men, in contrast to many previous cognitive tests of inhibition. Bjorklund and Kipp (1996) concluded that when a female advantage was observed, it could be classified as weak or moderate. However, we observed what Cohen would consider as a medium to large effect size (d = 0.63). The possible importance of peripheral information for generating a female advantage effect is supported by other sex differences work that also involves the processing of flanking information. Alongside general attention research (e.g., bottleneck theories; Broadbent, 1958), Field Dependency was an early (i.e., 1950s) dimension of individual differences in perception and the Embedded Figures Test became the standard paradigm to examine this. In the basic task, participants are required to find a figure embedded, or hidden, among an array of lines that generate many figures. Thus, good performance requires participants to inhibit peripheral information. Witkin et al. (1954) classified such people as relatively field independent since they are not so influenced by the entire perceptual field. Maccoby and Jacklin (1974) reviewed 64 field dependency studies that included sex as a variable of analysis and found that of the 28 that reported a difference, 25 showed a male advantage. Thus, when we consider this work together with the flanker task, females do appear to have a greater propensity to process peripheral information. Future work could isolate the influence of flanking information by presenting all stimuli (i.e., Go and No-Go) centrally. The existence of a female inhibitory effect under such conditions would weaken any argument based on male/female perceptual processing differences. More generally, future work examining the female-evolved inhibition hypothesis needs to compare sex differences of inhibition within-participant for social and cognitive tasks. That is, compare a person's inhibitory ability when they perform both a cognitive and socially based task. The hypothesis has relied exclusively on comparisons across studies.

In sum, the present work examined the female-evolved inhibition hypothesis in which females are said to have evolved inhibitory mechanisms partly out of the need to inhibit inappropriate social/sexual behaviors. Although our results do not support the most stringent version of the theory, i.e., greater female inhibition only on tasks concerned with social processing, they do support a more liberal version which posits that evolved female inhibition generalizes to a range of tasks.

COMPLIANCE WITH ETHICAL STANDARDS

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Conflict of interest

The authors declare that there is no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the University of Essex Ethics Committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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Table 1. Descriptive statistics for the Go/No-Go task. Reported are means and SD for each measure, for each sex.

Measures	**Males**		**Females**	
	M	**SD**	**M**	**SD**
No. successful Go trials	79.39	1.25	77.41	7.33
No. successful No-Go trials Overall	16.85	3.54	18.53	1.32
No. successful No-Go trials Left visual field	8.58	1.62	9.47	0.92
No. successful No-Go trials Right visual field	8.27	2.01	9.06	1.05