ENCODING SEX RATIO INFORMATION: AUTOMATIC OR EFFORTFUL?

by

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B.A., State University of New York at Plattsburgh, 2008
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AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

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Abstract

Operational Sex Ratio (OSR: the ratio of reproductively viable males to females in a given population) has been theorized and studied as a construct that may influence behaviors. The encoding of sex ratio was examined in order to determine whether the cognitive process underlying it is automatic or effortful. Further, the current work examines whether OSR or Adult Sex Ratio (ASR: the ratio of adult males to females) is encoded. The current work involved four experiments; two using frequency tracking methodology and two using summary statistic methodology. Experiment 1 found a strong correlation between OSR of conditions and estimates of sex ratio. Participants in Experiment 1 were uninformed on the purpose of the experiment, thus the strong correlations between actual and estimated sex ratio suggest a level of automaticity. Experiment 2 found a strong correlation between the ASR of conditions and estimates, suggesting that individuals do not encode OSR over ASR. Experiments 3.a. and 3.b. demonstrated automaticity in estimates of sex ratio from briefly presented sets of faces, for two different durations: 1000ms and 330ms, the later of which is widely accepted as the length of a single eye fixation. Overall this work demonstrated a human ability to recall proportion of sexes from arrays of serially presented individuals (Experiments 1 and 2), and that ASR is encoded when participants are presented with conditions including older adults. This work found the encoding of sex ratio to be highly automatic, particularly stemming from the results of Experiments 3.a. and 3.b. Conclusions from this work help to verify previous research on sex ratio's effect on mating strategies through evidence supporting the automatic nature of encoding sex ratio. Further, the current work is a foundation for future research regarding sex ratio, and leads to several proposals for future endeavors.

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This dissertation is dedicated to Matthew Alan Cahill who has supported me every step of the way, and cheered me on when I needed it most.

Chapter 1 - Introduction

Any snapshot of any part of the world contains a multitude of characteristics and minutiae- it is a wonder that we are able to take in the information we need to survive. Imagine for a moment, a parallel existence where we are not able to focus our attention, and are forced to try to make sense of the milieu without the ability to attend to specific features. It is almost comical to think of the thought process that would stem from this existence. Having to take in every single thing in our field of vision, how would we parse out information? How would we give meaning to what we see? How would we differentiate among stimuli? The mere notion is staggering. Fortunately, that thought experiment ends now, giving us our attention and ability to utilize those mechanisms to make our way through the environment on a daily basis across our lifespan.

One such influx of stimuli information that the visual system is responsible for encoding and parceling information from is Sex Ratio – the number of men and women in a population. For sex-specific factors needs, the ability to detect and parcel out sex ratio is vital. The current work focuses specifically on Operational Sex Ratio (OSR): the ratio of reproductively viable males to females in a given environment (Schmitt, 2005), and our ability to encode that information as well as Adult Sex Ratio (ASR: the ratio of males to females in a given environment, sometimes referred to as tertiary sex ratio, Delguidice, 2012). More specifically, how people encode OSR information is an aim of the current work.

Why would something like sex ratio be meaningful? Sex ratio, and more specifically, Operational Sex Ratio, has implications for one of the most basic tenets of human existence: mating. Darwin (1859) illuminated the importance of mating in terms of survival and reproduction, and this was more recently emphasized by Richard Dawkins (1976): mating and reproducing are the *reasons* we are on this earth. Dawkins stated that reproducing and passing on our DNA to subsequent generations are the sole reason for our existence. Although Dawkins's statement may seem myopic, his rudimentary point has prevailed through generations of evolutionary work, and is one element responsible for the vast extant literature on human mating behaviors.

Operational Sex Ratio (OSR) has been researched as a variable responsible for predicting behaviors. Several researchers have looked at OSR, examining the ways in which biased versus equal or unbiased OSRs affect behavior in humans, such as intrasexual competition (for reviews, see Dillon, Brase, & Adair, 2015; Emlen & Oring, 1977; Kvarnemo & Ahnesjo, 1996), mating strategies (Schmitt, 2005), changes in divorce and marriage rates, predominance of single-motherhood and single-fatherhood, increased number of sexual partners in females, increased male displays of commitment (Kruger & Schlemmer, 2009; Kruger & Vanas, 2012; Hassinger & Kruger, 2013), age of mother at menarche, first birth, menopause, number of children produced, money spending and level of debt in males, as well as career aspirations and salaries in females (Griskevicius et al., 2012; Durante, Griskevicius, Simpson, Cantú, & Tybur, 2012; Marlowe & Berbesque, 2012). Despite the extensive literature using OSR as a predictor of behavior, there is *virtually no available* literature on Operational Sex Ratio and its cognitive components; i.e., the ways in which we encode and recall sex ratio information of a current environment. The current work addresses these cognitive questions, exploring how we process information about sex ratios. In other words, do we encode OSR information quickly and possibly even without attention? Specifically, the results of the present research define some of the parameters regarding the encoding of sex ratio information, which has been used as a predictor for mating-related behaviors. If sex ratio is not encoded and recalled with relative ease, prior research on

OSR would need to be reexamined for other variables that may have contributed to the behavioral changes found. Information on the cognitive processes involved in detecting and encoding sex ratio information will help to shape future research on behavioral links to OSR. It must be stated that due to the heteronormative nature of existing Operational Sex Ratio research, this work does not use the construct of *gender*, but instead focuses on biological *sex* (i.e., genetic sex, sex at birth).

Chapter 2 - Operational Sex Ratio

Operational Sex Ratio (OSR) has been examined and researched particularly in the mating domain – it has been used as an independent variable that has been found to affect mating behaviors and decisions. Mating behavior is most often seen in “mating markets”, which are essentially the pool of males and females within which an individual can find a mate (i.e., find a sex partner). Mating markets are analogous to economic, consumer markets. In mating markets, there are two major categories of “others” – potential *mates* and potential *rivals*. Assuming heterosexuality (which is commonplace in mating research), potential mates are defined as individuals of the *opposite* sex who are possible partners for sexual relationships. Rivals are defined as individuals of the *same* sex who are seeking the same possible partners as the focal individual.

In Operational Sex Ratio research, there is an emphasis on the difference between equitable sex ratios (similar proportions of men and women), and biased sex ratios (wherein one sex is scarce and the other plentiful). A biased sex ratio is one where the one sex is plentiful, and the other scarce. For example, a male-biased sex ratio would refer to a population comprised mostly of men, with few females, creating a disadvantage for males, as they have more rivals and fewer potential mates. A female-biased sex ratio would refer to a population with many women and few males, creating a disadvantage for females – they would have numerous rivals and few potential mates. In biased sex ratios, individuals of the scarcer sex have an abundance of mating opportunities, while the plentiful sex experience limited mating opportunities (Dillon, Adair, & Brase, 2015). Non-equitable OSRs are biased negatively for the predominant sex, as they have an increased numbers of rivals, thus increased competition for access to the scarcer sex, and biased positively for the scarcer sex, as they have more opportunities (which allows them to be choosier) for available potential mates and a relatively small proportion of rivals (Emlen & Oring, 1977). To explain mating markets in marketing terms, the exchange rate in the mating market is determined by supply and demand (Noë & Hammerstein, 1994). In other words, if there is a short supply of one sex, there will be increased demand for access to that sex. This supply and demand construct is what leads to complications (competition) between rivals for access to mates, and helps illuminate the relevance of Operational Sex Ratio to society.

Biology and Phylogeny of Operational Sex Ratio

Contrary to the biased mating markets described above, most sex ratios are equitable. Biologists have been intrigued by the homeostatic (i.e., 1:1) sex ratio in species since the days of Darwin (see Darwin, 1859). R.A. Fisher's 1930 seminal paper on sex ratio stability and continuity explained how most species have an equitable production of males and females. Fisher proposed that, because offspring have both a male and a female parent, whichever sex is currently in short supply in the environment would experience greater fecundity (Fisher, 1930). Fisher's theory is based on the notion that a genotype that produces a larger number of the minority sex within its own offspring would be favored by natural selection, until there is an equilibrium of the sexes (Wilson & Colwell, 1981). In other words, until there are even numbers of males and females in a given population, there will be a constant homeostatic selection pressure for an equal number of each sex such that – whenever an unequal sex ratio arises – the population, through reproduction, will attempt to restabilize the equality of the sexes. Fisher's model favoring equal numbers of males and females is robust – it has been mathematically demonstrated multiple times (for a review, see Werren, 1983). Therefore, it is particularly interesting that unbiased sex ratios exist, thus studying the effects of such populations is the natural progression from Fisher's theory.

Operational Sex Ratio research has been conducted on naturally occurring and experimentally manipulated biased populations. Hamilton (1967) reviewed “extraordinary” sex ratios – sex ratios that are not typically seen; those that are particularly biased towards one sex or another. Hamilton primarily addressed these biased sex ratios as a response to the Fisherian condition (wherein it is assumed that populations usually have a 1:1 sex ratio). Though Hamilton (1967) mostly discussed these extremely biased sex ratios in non-human species, the paper does provide some examples that are applicable to humans. For example, Hamilton claimed that biased sex ratios are adaptations of the populations that manifest them. A sex ratio of 1:1 is typically associated with monogamous species, which humans are generally categorized as. According to the Central Intelligence Agency’s World Factbook, the overall sex ratio for the world population is 101 males for every 100 females. The United Nations Statistics Division (2006) gives an overall sex ratio for the world population of 101.5 males for every 100 females. (The slightly higher number of males at birth is compensated for by higher childhood mortality rates for males.) It stands to reason that an equal number of males to females would result in monogamous relationships, wherein all reproductively viable persons are able to find a partner to reproduce with.

Different Operational Sex Ratios can be, and typically are, associated with various systematic variations in mating behaviors across species. Within nonhuman research, differences in OSR have been found to have reliable connections with traits such as intrasexual competition for mating seems to be partially determined by sex ratios (Dillon, Adair, & Brase, 2015), sexual dimorphism between the sexes, and the degrees to which males and females provide investment to offspring (Kokko & Johnstone, 2002; Kokko & Jennions, 2008). This can be integrated and compared with Trivers’ (1972) Parental Investment Theory, which provides a biological foundation for several specific sex differences. Parental Investment Theory states that whichever sex provides more resources to offspring (i.e., more parental investment), is the sex that is in higher demand on the mating market. In other words, the sex that contributes more to offspring is the one who picks the mate, rather than the one who strives to get picked. From a biological standpoint, parental investment is not merely something that begins at conception; typically, the sex in a given species whose gamete is larger and more "expensive" is the sex that is choosier in selecting a mate. For instance, whereas female mammals are born with a limited number of eggs, male mammals create sperm throughout their lifetime; thus eggs are larger and more expensive, whereas sperm are cheaply produced. Parental Investment Theory thus suggests that, for most species, the female will be the choosier of the sexes when it comes to selecting a mate. Despite biological factors promoting the position of human females as the choosier sex, when females are in a female-biased mating market (more females, less males), males can actually have a significant amount of choice within that mating market.

Biological theories on sex-specific behavior are paramount for our comprehension of sex-specific behavior, as well as understanding how biased sex ratios may intensify those differences. Parental Investment Theory postulates that the sex with the higher *minimum* parental investment (i.e., whoever is required to invest more in offspring, either metabolically or through behavioral investments) is the choosier sex when it comes to the mating market. Stone, Shackelford and Buss (2007) supported this, finding that the scarcer sex in a given population is able to be choosier on the mating market which allows that sex to increase their standards or minimum requirements in a mate.

The Psychology of Operational Sex Ratio

Biased Operational Sex Ratios

The existing Operational Sex Ratio literature focuses on behavioral changes associated with real or manipulated biased OSRs – often these behavioral changes are sexual in nature, either relating specifically to sexual behavior or sex roles, or relating to mating in a more indirect nature. Given that the only exclusionary criteria for OSR is a lack of reproductive viability, and the theory that reproduction is the ultimate goal of mating (Dawkins, 1976), this focus on mating comes as no surprise. Dillon, Adair and Brase (2015) cited biased OSRs as a causal predictor of intrasexual competition for access to mates. A biased sex ratio changes the likelihood of competition in the mating market, such that the abundant sex would experience an increase in intrasexual competition for access to the scarcer sex, whereas the scarcer sex would experience an increase in choosiness and unwillingness to settle for lesser mates.

In male-biased (numerous males, fewer females) Operational Sex Ratios, changes in behavior have continued to be substantially related to mating, whether directly (competition for females) or indirectly (increased spending, which may serve as a cue to females that the males have resources, a trait desired in a male partner by females (Kirsner, Figueredo, & Jacobs, 2003; Buss, 1989). Along with increased male intrasexual competition in male-biased OSRs, Schmitt (2005) found a higher level of *restricted* sociosexuality, namely monogamy, prolonged courtship, and increased emotional investment in long-term pair bonds. All of these traits are associated with female preferences in males (Buss, 1989). Conversely, *unrestricted* sociosexuality corresponds to increased short-term mating and lower levels of closeness in romantic relationships (Simpson & Gangestad, 1991). Unrestricted sociosexuality is more common in female-biased sex ratios. An increased rate of polygyny, a predominance of short-term mating, and an increase in number of sexual partners reported by females were found in more female-biased populations (Kruger & Schlemmer, 2009; Hassinger & Kruger, 2013).

In addition to partner mating relationship behavior, biased OSRs were associated with a change in family dynamics: female-biased (more females, less males) OSRs exhibited an increase of single-mother households, whereas male-biased OSRs demonstrated an increase of single-father households (Kruger & Schlemmer, 2009). Female-biased OSRs were associated with a larger percentage of women in the highest paying careers, and the average age at first birth was higher in female-biased OSRs than equal or male-biased ratios. Male-biased OSRs were associated with a decrease in overall fecundity (number of babies born: Durante et al., 2012). In addition to the typical family dynamic changes (single-parent households, fecundity), Griskevicius et al. (2012) established that male-biased sex ratios showed an increase in male spending, both in terms of number of credit cards owned, and average amount of debt males were responsible for. In other words, perceived scarcity of females led to an increased desire in males for immediate monetary rewards (which leads to debt in the long term). Essentially, males in a male-biased sex ratio are more likely to have more debt and spend more money, in theory as a means of demonstrating their ability to provide resources to females. Females in U.S. regions with male-biased OSRs showed increased preferences for high socioeconomic status mates (Pollet & Nettle, 2008).

Tracking of Operational Sex Ratio Information

The previous literature has demonstrated the importance of Operational Sex Ratio (OSR) for the assessment of sex role and mating behaviors. Before these relationships can be truly understood, we must first explore and analyze the cognitive foundation of processes involved in encoding OSR. It is of utmost importance to understand *how* we attend to sex ratios, as well as whether that process is automatic (i.e., happens without trying/without using attention) or effortful (i.e., happens only if cognitive resources are employed, using attention). If the process of encoding sex ratio is *effortful* (which requires focused attention), humans would likely be less accurate in estimating OSRs of novel environments – if they were not instructed to attend to the ratio information in advance. On the contrary, if the process is *automatic*, humans would be more accurate in estimating OSRs of novel environments without implicit instructions to do so. These statements stem from the notion that automatically extracted information can be encoded and recalled with little prompting, whereas effortfully extracted information is more difficult to recall, particularly without prompting (Zacks & Hasher, 2002).

Intriguingly, many of these articles (see Schmitt, 2005; Kruger & Schlemmer, 2009; Hassinger & Kruger, 2013; Durante et al., 2012; Griskevicius et al., 2012) *specifically* mention cognitive or perceptual mechanisms underpinning sex ratio effects, yet fail to propose any theories on how these mechanisms actually work. The amelioration of this gap in knowledge is one reason the current research is necessary; elucidating the mechanisms underlying Operational Sex Ratio encoding provides greater insight into human behavior, specifically behaviors associated with biased sex ratios. Much can be said about sex ratio and the behavioral changes it evokes, but these changes cannot be fully understood without a grasp on the mechanism(s) that encode(s) OSR. Subsequently, a key aspect of the current work is the examination of the cognitive processes associated with the encoding of sex ratio information, in addition to the examination of whether OSR is the sex ratio encoded, or it no such reproductive-related exclusionary criteria is made.

Adult Sex Ratio or Operational Sex Ratio?

Some researchers have begun to emphasize the difference between Operational Sex Ratio (OSR) and Adult Sex Ratio (ASR). OSR consists only of reproductively viable mates ages 18-49 (Marlowe & Berbesque, 2012), whereas ASR consists of all adult males and females including post-reproductive individuals (Del Giudice, 2012). The difference between Adult Sex Ratio and Operational Sex Ratio is fairly straightforward; biological differences exist between male and female humans above the age of 49 (i.e., the upper boundary of age for the OSR cut-off) – females experience menopause, but males are still able to reproduce. Though the purpose of the current work began with a focus on OSR, ASR may be the variable underlying the behavioral changes for which OSR has been suggested to predict. If OSR is being encoded, this information would be particularly useful for mating strategies. In other words, if we hold the information of the OSR of our mating market, we should, according to past research, adjust our mating strategies and other behaviors in order to reproduce, and these behaviors change according to the Operational Sex Ratio of our population. However, if Adult Sex Ratio (i.e., *all* individuals over the age of 18 with no exclusionary criteria) is encoded, it would likely still serve as a factor in choosing mate strategies because there is still a focus on the proportions of males and females, but it would be less precise. OSR would be more specifically useful for adjusting mating strategy selection, because it removes the non-reproductively viable from the ratio when making mating decisions. ASR, however, may be more generally useful for adjusting behaviors across many areas of life beyond mating strategies. This must accounted for when distinguishing between OSR and ASR. A contributing goal of this work is to determine if the sex ratio tracking abilities in humans are specifically tuned to OSR, or whether ASR is encoded or if both can be extracted and recalled. Are our abilities to encode and use sex ratio information specific to the exclusionary criteria for Operational Sex Ratio, or are our encoding processes sensitive to the more general Adult Sex Ratio?

From an evolutionary perspective, the issue of OSR versus ASR encoding reflects a question about the specificity of the evolved adaptation. Adaptations have been defined in a few different, but complementary, was. Buss (2012, p. 15) described adaptations as "evolved solution to specific problems that contribute either directly or indirectly to successful reproduction." G.C. Williams (1966) defined an adaptation as something that can be recognized as having evidence of special design. The evolved design of an organism includes parts of problem-solving mechanisms that solve a long-standing evolutionary problem. Williams defined the factors for recognizing adaptive "design" as economy, efficiency, complexity, precision, specialization, and reliability. In other words, the design is too good of a solution to an adaptive problem to have arisen by chance. Tooby and Cosmides (2005) describe the long-term scientific goal behind evolutionary psychology as the mapping of universal human nature. Tooby and Cosmides (2005) describe an adaptive behavior as "behavior that tended to promote the net lifetime reproduction of the individual or that individual's genetic relatives." (p. 21).

In a very broad sense, all cognitive structures exist due to processes that occurred through the course of evolutionary history, but the more relevant issue is the specificity of those structures and mechanisms. Within the current work, is any adaptation for tracking sex ratios specific to the domain of OSR or more generally designed for tracking ASR?

Chapter 3 - Cognitive Areas of Research and Processes

The cognitive processes that enable us to perceive our environment and encode information useful to our survival are of critical importance in research, particularly research examined through an evolutionary lens. In order to understand the cognitive processes responsible for encoding and recalling Sex Ratio information, it is necessary to first become familiar with several cognitive areas and methodologies. Some cognitive processes of importance to this work are cognitive load, attention, and working memory. First, however, social cognition must be addressed in order to create a basis of knowledge of how cognitive processes affect our social behaviors and attitudes.

Social Cognition

Cognitive processes exist that make people aware of group membership. Whether based on race, sex, or any other social variable, membership in a social group has a profoundly important influence on human behavior. Thus, the cognitive process at work when looking at sex ratios is *social categorization*, a phenomenon within the area of social cognition, which is the encoding, storage and retrieval of information about other humans that is relevant to categorizing them into groups (Macrae & Bodenhausen, 2000). Social categorization is an influential factor when researching interpersonal relationships, as well as the elements that contribute to decision making within the realm of sex ratio and mating.

Cosmides (1989) points out that in social cognition, the deterministic factor for what is adaptive and what is not is the intricate biological problem in itself, and that it is *not* susceptible to ad hoc theorizing. Tooby and Cosmides (2005) described Darwin's studies of plants that revealed complex organizational structures that seemed to overcome obstacles. They discuss the idea that, in order for something to be an adaptive process, it had to evolve in order to solve an adaptive *problem*. Tooby and Cosmides (2005) claimed that adaptive problems have two defining characteristics: 1.) they must be conditions that many if not most of our ancestors faced, reappearing throughout the evolutionary history of our species, and 2.) they must be able to be used by the organism to increase fitness (reproduction). Keeping these characteristics in mind, we can see how OSR may be a mechanism designed to solve the adaptive problem associated with mating. If encoding OSR helps to change the mating strategy of the individual dependent on the ecological context, fitness should increase, thus solving the adaptive problem of mating.

The specific type of social categorization necessary for the current work is the categorization of sex. Bem (1981) discusses how the phenomenon of perceived sex is derived from gender schematic processing. A schema is a cognitive structure, or network of organized associations that help us to piece together information about a specific topic. For example, gender perception is based on a series of traits or characteristics that provide one with the information about the sex of the individual. Bem (1981) claimed that schemas are used in order to characterize an individual as male or female. The current work gives participants the task of determining information about sex ratios from photographic stimuli, which requires a schema for determining sex. Lurye, Zosuls, and Ruble (2008) replicated and extended Bem's work, suggesting that the schemas responsible for determining sex are essentially constructed from perceptual characteristics that would make an individual representative of his or her group. For example, does this individual possess traits that would make them an adequate representative of their sex group? If humans were without the ability to determine sex, it would be quite difficult if not impossible to task participants with identifying sex ratios. Therefore, for the current work, it is important to keep in mind social categorization: sex is constructed cognitively through cues. Because of this, the current work makes use of two facial databases, NimStim and the Parks

Aging Database (Tottenham et al., 2009; Minear & Park, 2004) for stimuli. These databases have already been used in psychological research, and it is worthwhile to note that most of the images of men are “typically” male, following a male schema – shorter hair, broad chin, etc., and most of the images of women are “typically” female, following a female schema – longer hair, makeup, etc. Once an understanding of social categorization has been established, cognitive processes specific to encoding and recall can be addressed.

Cognitive Load, Attention, and Working Memory

Attention is the behavioral and cognitive process whereby we selectively process one aspect of the environment but other irrelevant (ignored) stimuli (Treisman & Gelade, 1980). Attention is a selective process due to the limits of our cognitive capacity (Carrasco, 2011). In other words, attention can help decrease cognitive load – if we can focus on what is important, our cognitive processes are not slowed down by irrelevant information, because there is no focused attention devoted to it. The limited capacity of attention creates a situation wherein a person under large cognitive load (paying attention to more than one thing, performing multiple tasks, etc.) will demonstrate impaired effortful processing (Carrasco, 2011; Cowan, 2010; 2000; Sweller, 1994; Lavie, Hirst, de Fockert, & Viding, 2004). Specifically, Marchant, Simons, & de Fockert (2013) state that the cognitive mechanisms that allow for spatial focusing of attention, feature binding, and object recognition are limited in capacity. In other words, humans are able to cognitively process a multitude of tasks, but there are limits as to what we can do, how much we can do at a time, and most essentially, how our ability to perform effortful processes is affected by cognitive load.

A lot of attention (pun intended) in research has been paid to the limited capacity of working memory. Working memory is the memory that we use to store and manipulate newly presented information for short periods of time (Baddeley, 1992). Working memory is limited, and attention can help to decrease the amount of information needed to be stored in working memory: if we are paying attention to stimuli in an experiment and not paying attention to our surroundings or the things we plan on buying at the supermarket after the experiment, we are using less working memory, thus the working memory being used should be holding the stimuli information, rather than spurious variables. The key limitation for the current work is working memory – can an array of faces and their biological sex identification be encoded and stored long enough to recall an estimate of the proportion of the sexes? Cowan (2010; 2000) and his predecessor, Miller (1956), have discussed human reliance on our ability to "chunk" information. Both Cowan (2010) and Miller (1956) have proposed estimates for the size of a mental "chunk" and how many chunks can be held in working memory. In relation to the current work, Miller believed that humans could hold 7 plus or minus 2 chunks of information, while Cowan (2010; 2000) stated that the capacity is closer to 3 or 4 chunks of information. Individuals tasked with tracking the frequency of the sexes or determining the sex ratio of a given set, the males could be put together as a chunk, and the females another chunk.

William James (1890) described two forms of attention, one being passive, reflexive, and involuntary, which he termed exogenous/transient attention (we now call this automatic, though a distinction must me made that automatic processes that require NO attention should not be categorized as a form of attention), the other being active and voluntary, which he termed endogenous/sustained attention (we now refer to this as effortful). Fully *automatic* processes cannot be improved through the use of practice or other memory techniques – they require little to no cognitive effort, and generally do not show impairments under the conditions of cognitive load. It is necessary to point out that once a process is automatic, it does not require further practice, but many processes *become* automatic through extended practice – take, for example, reading. As a small child, reading is a difficult endeavor as sounding out words and understanding syntax is learned, but once one has been reading for years, it is impossible *not* to read something written that is placed in front of them. To some extent, just as the old phrase "practice makes perfect" says, practice can make processes automatic. *Effortful* processes, on the other hand, require cognitive resources, can be improved with practice (Hasher & Zacks, 1979), and show marked impairments under cognitive load conditions. In comprehending automaticity, it is important to distinguish among levels of automaticity. A flashing light in our peripheral vision will capture our attention, but this does not mean that the cognitive processes engaged by the light involved focused or effortful attention. Automatic processes that become automatic over time involve cognitive processes that involve choosing *what* to pay attention to. Completely automatic processes can capture our attention whereas semi-automatic processes may call for the use of minute amounts of attention.

Cognitive load is the reason for the difficulties we face when learning new tasks. These difficulties can fluctuate dramatically: learning can be very easy or impossibly hard. Whereas some tasks require fewer cognitive resources to complete, others require much more, which makes attention that much more necessary (Sweller, 1994). Automatic processes are less influenced by cognitive load than effortful processes; this has been demonstrated through the use of varying search tasks. For example, Shiffrin and Schneider (1977) showed that controlled searches, which involved effortful processing, demanding a large portion of attentional capacity. Controlled searches are often serial (serial processing), meaning a participant has to look at every piece of information individually. These tasks are strongly dependent on the set size of the search (i.e., the number of items to be searched). Conversely, there is parallel processing (where one sees entire sets of stimuli at a time). Automatic processing demands little if any attention, operates in parallel, is relatively unfazed by the size of the search area, and once learned these processes are difficult to suppress (see Stroop, 1935), and. The way we encode the information from an array (i.e., controlled or automatic, serial or parallel) is critical for understanding how stimuli are processed, and how much attention is necessary for the information to be encoded.

Chapter 4 - Methodologies for Cognitive Process Experimentation

The current work adapts two existing methodologies in order to examine the underlying cognitive processes related to encoding Sex Ratio information: frequency tracking and summary statistics.

Frequency Tracking

Humans are able to acquire knowledge on the relative frequency with which events occur – event types can range in stimuli from individual letters to disease prevalence (Hasher & Zacks, 1979). Substantial evidence suggests that people are sensitive to frequency of information or item occurrence, and this information is used to solve a wide range of cognitive and behavioral problems (see Hasher & Zacks, 1979; 1984; 2002 for review). Hasher and Zacks' (1979) work on frequency processing is seminal in the field of cognition. Specifically, they focused on how attention plays a part in frequency tracking – is attention a necessary aspect to frequency tracking? They then proposed that encoding operations vary in their attentional requirements, and those mechanisms or operations that require *minimal* attention are automatic. Their framework for conceptualizing memory processing had two basic tenets; one that there is a continuum of attentional requirements in encoding, and the second is that there is a variable capacity to attention, which interacts directly with encoding processing.

In order to explore the attentional requirements for frequency tracking, Hasher and Zacks (1979) employed the use of two groups; one group was informed that after a serially presented array of words, a question would be presented asking them to recall the frequency with which they saw various words from a subsequent list (wherein some words had been repeated numerous times and some had not). The second group was uninformed of the frequency aspect of the memory task following the stimuli presentation. Findings suggested that both groups performed equally well on the recall task, demonstrating that directions or hints in relation to the point of a task did not affect the accuracy or performance participants showed when estimating the frequency with which words were presented. Hasher and Zacks (1979) found that explicit instructions that frequency estimates would be required (in other words, telling the subjects to attend to frequency) did not improve the performance of participants' estimations of frequency, thus implicating automaticity.

Zacks and Hasher (2002) reestablished their assertions that frequency of occurrence information is processed automatically, and despite critics of the theory, continues to support the 1979 hypothesis regarding the automaticity of frequency encoding, citing empirical evidence for automatic frequency encoding that has stood the test of time. Researchers such as Scarborough and Cortese (1977) also have provided evidence supporting the notion that as frequency of occurrence of a stimulus is increased, estimates of the frequency increase linearly. In other words, the number of times a stimulus is displayed, and participant estimates on the frequency of stimuli presentation correlate strongly. Hasher and Zacks (1979) were rather specific when describing their conceptualization of automatic encoding; they stated that automatic encoding of information only minimally affects an individual's capacity to process other components. It is interesting that attention is not brought up explicitly in their description of automatic encoding, as level of attention is a key way to determine whether or not a process can be deemed automatic (see Shiffrin & Schneider, 1977). Hasher and Zacks (1979) state that automatic processes only take up minimal attentional capacity. The similar performance displayed by both groups suggested automaticity in frequency tracking. In other words, one cannot ignore sex ratio that is placed in front of them - individuals encode the information regardless.

Beyond frequency tracking of specified stimuli, estimates of frequency may be affected by how available a memory of a stimulus is that was presented. When researching the validity of frequency and probability judgments, Tversky and Kahneman (1973) discovered the availability heuristic. Tversky and Kahneman (1973) noted that when judging the probability of an event by the number of events of that type in memory may influence frequency estimations. An example is divorce rate – people recall divorces within their social circles, and as such, one might claim there is more divorce in America than there actually is if they come from a group of people where the divorce rate is high. The availability heuristic is essentially a mental shortcut (much like chunking in working memory), wherein probabilities or frequencies are judged by how easily or immediately examples of the event come to mind. The availability heuristic brings up an important issue: are people actually judging frequencies of stimuli presented in an array or a set, or are their frequency judgments coming from a heuristic based on the available instances that come to mind? In other words, if a participant sees a series of photos of a particular OSR, will their estimate of the OSR be based on the stimuli, or will it be based on the participant's memory of the population in which they live?

Some critiques of frequency tracking methodology have suggested that frequency encoding is *not* automatic (Brown, 2002; Greene, 1992; Haberstroh & Betsch, 2002), whereas others have provided additional evidence for automaticity in processing frequencies (Greene, 1992; Hintzman, 1976). Against the automaticity in frequency tracking, Greene (1992) pointed out that it is possible to set up an experiment where participants pay almost no attention to the stimuli, and thus perform poorly on recall. Greene further pointed out that alterations in attentional capacity should have no effect on an automatic process. An example of this point is that children, adolescents, and the elderly should all perform at the same level – evidence for which is mixed. Nevertheless, Greene (1992) also provided evidence supporting the automaticity of frequency processing, stating that practice does not increase performance on frequency estimations. Questions have been raised regarding the legitimacy or accuracy of frequency encoding research, some have suggested that low frequencies tend to be overestimated and high frequencies tend to be underestimated (see Zechmeister & Nyberg, 1982).

Of critical importance to the current work, is whether or not Sex Ratio frequency information can be tracked, and if so, whether or not this process is automatic or effortful. If the process is automatic, there is an implication that people cannot ignore the proportion of the sexes in a population; it is picked up without effort and without attention.

Summary Statistics

Summary statistics in memory and cognition refer to the statistical averaging of features of a group of objects, negating to some degree the limitations of focused attention on our ability to extract information from a set of stimuli (see Ariely, 2001). Summary statistics are used in research on briefly presented of stimuli items. Ariely (2001) pointed out that sets of objects are common occurrences that we see daily, from a group of trees, to a parking lot filled with cars, to a row of fences. Ariely claimed that while each item in one of these sets is distinct and discriminable, it is hard (due to our limited cognitive capacity) to take in all the information from all items in a set and remember it once we have looked away from the set. Ariely (2001) proposed that the visual system creates a specific representation among sets of similar objects to lessen the cognitive load – again this process is quite similar to Cowan (2010) and Miller's (1956) theory of chunking. These specific representations are known as summary statistics, which are proposed (by many) to be an automatic process (Ariely, 2001; de Fockert, & Marchant, 2008; Haberman & Whitney, 2007; Marchant, Simons, & de Fockert, 2013).

Chong and Treisman (2003) added to Ariely's (2001) notion of specific representations through summary statistics by suggesting that statistical properties such as mean, range and variance of size, color, and orientation of items in a set play a part in forming schematic representations of the set. Participants were shown to be better at judging the mean size of a set of circles than at judging the size of any individual circle within the set (Ariely (2001); Ariely & Burbeck, 1995). de Fockert and Wolfenstein (2009) similarly stated that the accuracy of mean size estimations are just as good as the accuracy of mean size estimations of individual items. Ariely (2001) and Ariely and Burbeck (1995) found that mean size estimates in sets of heterogeneous circles were *more* accurate than estimates or judgments of any randomly selected item within the set. Chong and Treisman (2003) suggest that the process of extracting something such as mean size may be a parallel process – in other words, when looking at a set we take in the features of all items rather than the features of individual items one at a time. VanRullen, Reddy, and Koch (2004) discussed this concept, suggesting that parallel processing is preattentive, which means it is not using attention. Though multiple studies on summary statistics use stimuli such as shapes or lines, research that is most relevant to the current work is summary statistic research with facial stimuli.

Haberman and Whitney (2007) used faces with morphed expressions indicating various emotions as set stimuli, and asked participants to identify the emotion of sets of faces. Participants summarized the information from the set of objects and lost the original representation of the individual items that made up the set. These results provided evidence suggesting that when shown for a brief duration – even for stimuli as complex as faces – summary information is encoded. Haberman and Whitney (2007) made an important claim about mean extraction: it generalizes to other emotions, and even other dimensions such as gender. de

Fockert and Wolfenstein (2009) conducted studies to further examine whether summary statistics of facial sets can be extracted in the same manner as stimuli such as circles (see Ariely, 2001). Four faces of different identities were briefly presented to participants, followed by a single test face, before participants were asked to judge whether or not the test face had been present in the preceding set of four faces. The test face was either one of the four faces shown in the array, or a digitally morphed average of the four faces. Their findings suggest that, even for complex stimuli such as faces, an averaging process that results in summary statistics occurs. Furthermore, de Fockert and Wolfenstein (2009) found that when the given test face was a digitally morphed average of the four face set, more participants judged the test face to be one of the faces seen in the set than when the test face was a face that had been shown in the set. This helps elucidate Haberman and Whitney's (2007) statement about participants gaining statistical information about a set while losing the original set representation.

Also particularly relevant to the current work are the findings of Reddy, Wilken and Koch (2004), who explored the attention costs required for face-gender discrimination. Face-gender discrimination was examined using incredibly short time durations (26ms). Participants viewed faces and indicated the gender of the face using two keys on the keyboard. This was carried out in two conditions, one where the gender discrimination was the only task, and one where another task was carried out at the same time. Reddy, Wilken and Koch (2004) found little difference in the results for the face-gender discrimination between the single and dual task, which suggests, that face-gender discrimination is possible in the near absence of attention (their sets were displayed for a mere 26ms).

Haberman and Whitney (2007), unlike researchers who used rather simple stimuli in their summary statistic research (e.g., Ariely, 2001), showed face stimuli for a duration of 2000ms – a duration like this is much longer than the 330ms known to be the duration for a single eye fixation. de Fockert and Wolfenstein (2009) used durations as short as 500ms. Although much summary statistics research uses short durations, Haberman and Whitney (2007) stated that faces are highly complex stimuli, which led to their increase in duration times. This is of particular importance due to the nature of the current work, as sex ratio stimuli must be complex in order to denote biological sex while remaining ecologically valid.

Chapter 5 - The Current Work: Specific Aims

The current work has been designed to explore the cognitive mechanisms responsible for encoding and recalling information about Sex Ratio. Is the frequency of one sex (which is easily calculated into sex ratio) tracked? If so, is it easily recalled? Is this process automatic, or does it require attention, and if so, how much? Due to the substantial research on behavioral changes associated with biased sex ratios, this work should help determine the validity of those studies – if humans were unable to encode sex ratios, it is highly unlikely that they would be able to use sex ratios to make decisions regarding mating strategies. Using frequency tracking and summary statistic methodology, the current work manipulates perceived sex ratios using images from two facial databases (Minear & Park, 2004; Tottenham et al., 2009).

Further aims of the current work focus on whether Adult Sex Ratio (ASR) or Operational Sex Ratio (OSR) is encoded. If OSR is encoded over ASR, implications may be made that the sex ratio humans encode is used entirely for mating purposes, whereas if ASR is encoded over OSR, the link to adaptiveness would be weakened, as it would eliminate the argument that automatic OSR processing would increase reproductive success through changing mating strategies according to the OSR of a population. Assumedly, ASR estimation would be less useful for decision-making regarding mating strategies in the moment. Additionally, whether participants are able to encode and recall *both* ASR and OSR information depending on dependent measure prompts is examined. To further explore whether encoding sex ratio is automatic, summary statistic methodology is used to determine the stimuli set duration boundaries associated with automatic processing.

Chapter 6 - Experiment 1 – Frequency Tracking

Experiment 1 was designed to explore the frequency tracking of Operational Sex Ratio. In order to attend to the frequency tracking capabilities people have for sex ratios, it must first be established that frequency of both identity (frequency of individuals) and biological sex (frequency of men and women) of stimuli that fall into these category of stimuli that can be used in frequency tracking experiments. In order to determine whether these stimuli can be used in frequency of occurrence methodologies, pilot studies were run to establish that the frequency of identity and biological sex can be tracked.

Pilot Studies

Two pilot studies were run for Experiment 1. The first assessed whether frequency of identity could be tracked – in other words, could participants filter out repeated exposure of the same people (a frequency that would not contribute to overall OSR) versus exposure to different people (a frequency that would contribute to overall OSR). The second pilot study assessed whether frequency of biological sex (i.e., proportion of females and males) could be tracked – in other words, could participants track the overall percentage or proportion of one sex (in order to calculate sex ratios).

Pilot Study 1 – Frequency Tracking of Identity

Following Hasher and Zacks' (1979) methodology of serially presented stimuli with two participant groups (one informed of the frequency task at the end of the series, one uninformed), pilot study 1's participants were randomly assigned to one of two conditions: informed vs. uninformed. Those in the informed condition were told that they would be seeing a series of faces and then would be asked to estimate the number of times they had seen a subset of those individual faces, whereas those in the uninformed condition were merely told that they would see a series of faces and then be asked some questions related to the series.

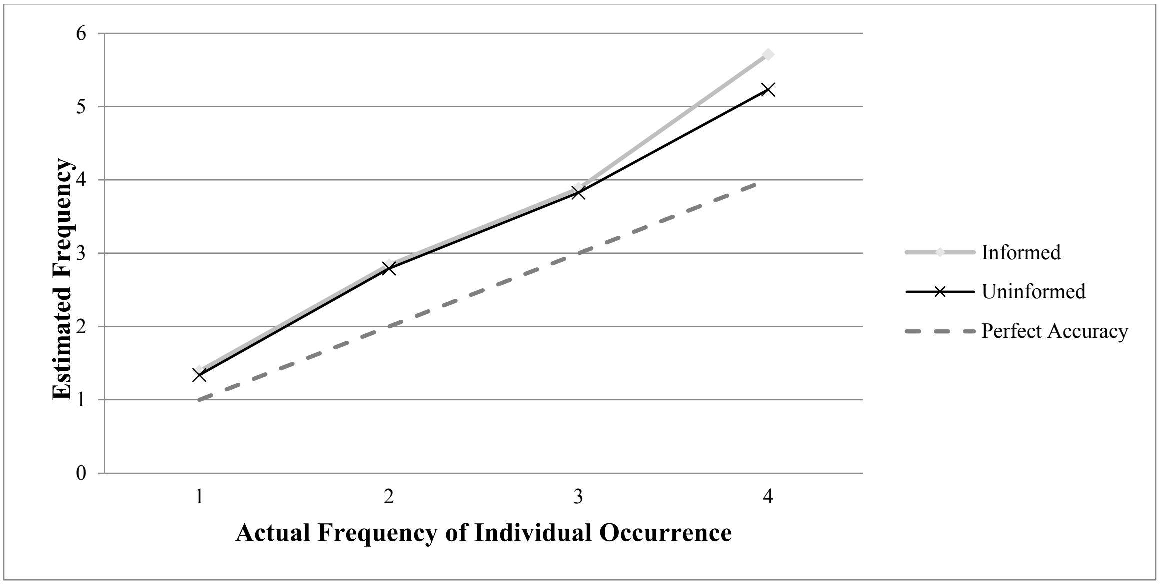
Participants were recruited using Amazon's Mechanical Turk, which is a service offered through amazon.com that recruits participants and compensates approximately 15¢ per study. Two-hundred and sixty seven participants' data were used of 315 total responses – 48 responses had incomplete data and were not included in the analyses. The sample was comprised of 27.5% male participants and 72.5% female participants. Participant age range was 18-37 ($M = 19$, $SD = 2.13$).

After randomly assigning participants to the aforementioned conditions, participants then saw four blocks of 15 faces each (in random order). Four individuals' faces were included in each of the four blocks, four faces were included in three blocks, four were included in two blocks, and the rest of the individuals' faces were presented only in one block. Faces were presented serially, and below each face participants were asked to rate the face on attractiveness (1-10 scale). After viewing all 60 faces across four blocks, participants were asked basic demographic questions. Participants were then presented with 24 individuals (presented in random order): all 12 who had been seen repeatedly, and 12 novel faces. For each of the faces, participants were given a text box and asked to estimate how many times they had seen each face.

Findings from this study suggest that frequency of individuals can be tracked and, though frequency estimations are not 100% accurate, a linear relationship exists between the number of times an individual is shown and the estimation for how many times participants have seen that individual $r = .998$, $p < .002$. Independent samples *t*-tests were run for each level of the repetition condition; for individuals displayed 4 times, $t(96) = 1.66$, $p = .099$ (Informed $M = 5.71$, $SD =$

1.43, Uninformed *M* = 5.24, *SD* = 1.35), for individuals displayed 3 times, *t*(96) = .227, *p* = .821 (Informed *M* = 3.88, *SD* = 1.14, Uninformed *M* = 3.83, *SD* = 1.04), for individuals repeated 2 times, *t*(96) = .176, *p* = .861(Informed *M* = 2.83, *SD* = 1.19, Uninformed *M* = 2.80, *SD* = .97), and finally for individuals displayed once, *t*(96) = .241, *p* = .810 (Informed *M* = 1.39, *SD* = 1.21, Uninformed *M* = 1.35, *SD* = .55). Results also demonstrated that accuracy of frequency tracking between informed and uninformed conditions showed no significant difference. In other words, the performance of an individual did not become better or worse with information about the purpose of the task and the following questions (see Figure 6.1). The complete lack of statistically significant difference between conditions is theoretically important: those told they would be asked about the frequency (i.e., basically told to pay attention to the number of times an image was presented) were no better at judging frequencies than those who were not told. This means that intentional attention to frequency does not improve performance, which suggests that the tracking of face frequency is an automatic task. Further, *all* of the estimates, regardless of their condition were overestimated slightly. We attributed this to the lack of anchors in the text – participants were given an open-ended statement after viewing 60 images. According to Brown (1995), overestimation occurs in frequency tracking when participants rely on non-numerical strategies and are not given information regarding the upper boundary of the response range. In other words, participants did not know the highest frequency was 4, no anchors were given, and thus overestimations were made.

Figure 6.1. Frequency of Identity Estimates



Pilot Study 2 – Frequency Tracking of Biological Sex

Having established that frequency of individuals' faces can be tracked in the first pilot study, a second pilot was run to examine whether sex ratio (or, operationally defined as the frequency of biological sex which is used to calculated into sex ratio) could be tracked. The same conditions and methodology as pilot study 1 were implemented.

Participants were recruited using Amazon's Mechanical Turk. A total of 143 participants took part in the study, only 124 participants' data were used in analyses – all incomplete data were deleted. The sample consisted of 47.7% male participants and 52.3% female participants. Participant age range was 18-65 (*M* = 32.30, *SD* = 11.30). Participants were randomly assigned to informed or uninformed conditions, and then randomly assigned to one of three arrays of 20 faces. The three OSR conditions were comprised of faces with either 1.) 75% Female / 25% Male, 2.) 50% Female / 50% Male, or 3.) 25% Female / 75% Male proportions. After viewing one of the three sex ratio conditions, participants were presented with two text entry boxes, and asked for the percentage of males and females. Again, no difference was found among the informed vs. uninformed conditions, and a linear relationship between actual proportion of males/females and estimated proportion was found; $r = .919$, $p < .001$.

Summary of Pilot Study Information

These pilot studies provide evidence suggesting that the mechanism(s) responsible for frequency tracking can and do track the frequencies of individuals as well as the relative frequency of biological sex, which permits hypotheses regarding the frequency tracing of sex ratio. Hasher and Zacks (1979) used the lack of difference between informed and uninformed conditions to suggest that there is an absence of attention in the process, which to them suggests automaticity. No significant difference between the performance of the informed and uninformed groups emerged for either pilot study. These results support Hasher and Zacks' (1979) position that frequency encoding and accuracy does not depend on whether or not participants are informed of the task at hand. Thus, the current work only uses the "uninformed" condition, which may negate any deliberate attention being paid to the frequency of the sexes.

Experiment 1

Stimuli sample size for Experiment 1 was based on previous research using manipulated sex ratios. In the Operational Sex Ratio literature, there were two types of samples: manipulated samples with participants (Griskevicius et al., 2012; Durante et al., 2012) which ranged in sample size from 89 to 205, and census data work (see Kruger & Schlemmer, 2009; Kruger & Vanas, 2013; Hassinger & Kruger, 2013; Griskevicius et al., 2012; Durante et al., 2012), where the information came from census data collections. The current work therefore used sample sizes within the range of 89-205. Using G*Power confirmed the sample size we used would allow us to detect a correlation of at least .5 at a power of .95.

The findings from these pilot studies lead to a directional hypothesis – frequency tracking has been found to be encoded, specifically that of identity and biological sex. Because frequencies were tracked in linearly, Experiment 1 has one unidirectional hypothesis:

> Participants will be sensitive to the OSR of a given series of images, such that actual and estimated values will correlate strongly. In other words, it is expected that participants will encode the relative frequency of men and women from a serially presented set of faces. A linear relationship between frequency judgments and the actual OSR frequency will be established.

Methods

Participants

Participants were recruited through the Kansas State University SONA system, a recruitment tool at the university where all students enrolled in Introduction to Psychology are required to complete 7 credits in order to pass the course, as well as some students from upper level courses who are compensated with extra credit. One hundred and eighty-seven participant's data were used for analyses. The sample was comprised of 36.9% male participants and 63.1% female participants. Ages ranged from 18-35 (*M* = 20.86, *SD* = 3.79). Due to the heteronormative nature of this work, only those data from self-reported heterosexuals were included – once the data were downloaded, cases of individuals who had not reported their sexual orientation as heterosexual were deleted.

Materials and Procedure

Experiment 1 was run using an online survey software package, Qualtrics.com. Images of male and female faces came from the NimStim Database (Tottenham et al., 2009) and the Parks Aging Faces Database (Minear & Park, 2004). As Experiment 1 was designed to test Operational

Sex Ratio, only faces between the ages of 18-49 (a commonly accepted age range for OSR see Emlen & Oring, 1977; Schmitt, 2005; Stone, Shackelford, & Buss, 2007) were included in the arrays.

First, participants read informed consent information and answered basic demographic questions. Participants were then randomly assigned to one of five sex ratio conditions (see Table 6.1 for sex proportion per condition). As a precaution, to increase the likelihood that participants actually looked at the faces, rather than click through the study without viewing the images, participants were asked to estimate the ages of the individuals shown – this was a way to ensure that participants looked at the stimuli (See Appendix A).

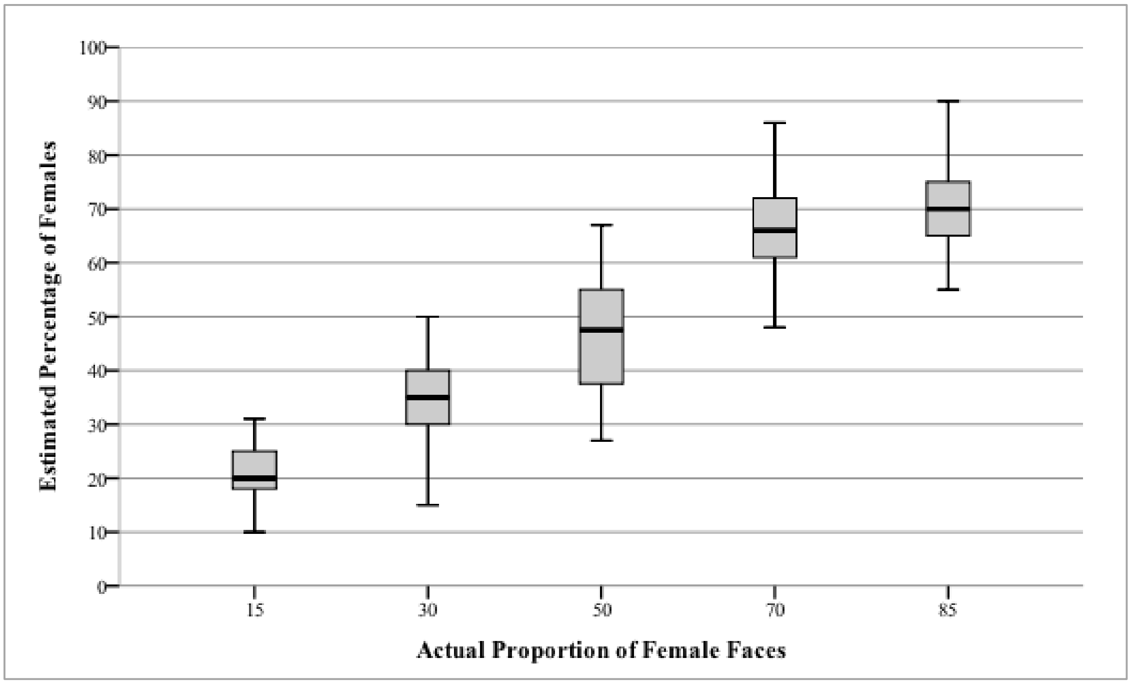
After viewing a series of images from one of the five conditions, participants were presented with the following question; "You just saw a series of faces. Please indicate the answer the best fits the proportion of sexes." This question was accompanied with a sliding scale (see Appendix B) with five anchors; "Entirely Male", "Mostly Male >75%", "Equal Males and Females", "Mostly Female, >75%", "Entirely Female."

Note that data provided from this question came out to a range of numbers from 0-100, which, due to the location of the anchors, makes correct answers for each condition the *percent of females* in that condition.

Results

Incomplete responses were removed from the data, as were univariate outliers, as identified from z-scores of the demographic variables (three were removed due to age). Of 254 initial responses, the data from 187 were used for analyses. The unidirectional hypothesis of Experiment 1 stated that actual and estimated values would correlate strongly. This hypothesis was supported; a Pearson correlation was used to assess whether participants were sensitive to sex ratio, correlating the actual values (the percent female of each condition: 15, 30, 50, 70, 85) with estimated values, which yielded a strong positive correlation; $r = .90$, $p < .001$ (See Figure 6.2). This result suggests that people are in fact sensitive to frequency of occurrence of sex and can thus encode sex ratio.

Figure 6.2. Frequency Tracking of Operational Sex Ratio



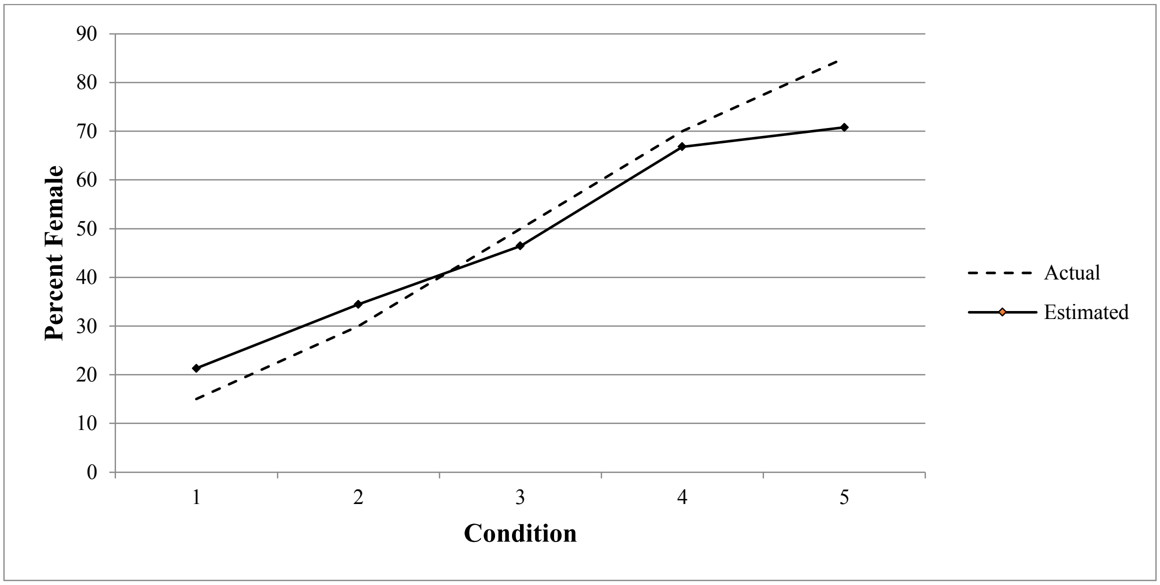
One-sample *t*-tests were used to determine whether a significant difference existed between the actual percentage in the condition and the estimated values: for the 15% Female condition; $t(36) = 6.97$, $p < .001$, $d = 2.32$, for the 30% Female condition; $t(37) = 3.37$, $p = .002$, $d = 1.11$, for the 50% Female condition; $t(39) = -2.15$, $p = .038$, $d = .69$, for the 70% Female condition: $t(36) = -2.095$, $p = .043$, $d = .7$, and for the 85% Female condition, $t(34) = -9.99$, $p < .001$, $d = 3.43$ (See Table 6.1 for means and standard deviations). The significance found for all one-sample *t*-tests indicates that participants increase their frequency estimation as actual frequency increases, but their accuracy is not perfect.

Table 6.1. Means and Standard Deviations for Operational Sex Ratio Conditions

Condition	OSR	Mean	Standard Deviation
1	15% Female / 85% Male	21.32	5.52
2	30% Female / 70% Male	34.45	8.13
3	50% Female / 50% Male	46.43	10.51
4	70% Female / 30% Male	66.81	9.26
5	85% Female / 15% Male	70.77	8.43

To further explore and examine the relationship between actual and estimated values, a one-way between subjects analysis of variance showed that the effect of condition was significant: *F*(4, 186) = 220.127, *p* < .001, providing further evidence to support the hypothesis. A (Tukey) post hoc analysis of this ANOVA demonstrated that 5 conditions were all significantly different from one another, with the exception of conditions 4 and 5, which were not significantly different from each other (see Table 6.1 and Figure 6.3 for more information).

Figure 6.3. Estimated and Actual Mean Percentage for Each Condition



Note: Figure 6.3 shows the correct responses by condition on the “actual” line, which is not perfectly straight because the percentages of females in the conditions were not equidistant from each other.

Discussion

Results suggest that individuals are able to extract the relative proportion of the sexes from a serially presented set of faces. In other words, the frequency of the sexes is in fact being encoded, and participants are able to estimate that proportion in a linear fashion – that is to say, as the proportion of the sexes became more female biased, so did the estimates (see Figure 6.2). The findings support the hypothesis, as well as Hasher and Zacks' (1979; 1982; 2002) theory that frequency of occurrence is tracked for various types of stimuli. Because participants were uninformed of the task, the assertions made by Hasher and Zacks are supported; this process is automatic in nature and requires little attention.

Despite the strong correlation between actual percent and estimated percent, one sample *t*-tests revealed that for all conditions, the mean estimated values were significantly different from the actual values (actual values being % female per condition, see Table 6.1). This finding was not entirely unexpected. It must be taken into account that the wording of the hypothesis was not incidental, it was proposed that people would be *sensitive* to the sex ratio, not that they would estimate percentage of females with complete accuracy. Thus, there is no surprise that the estimated values for each condition did not match up perfectly with the percentage of females. In order for perfect accuracy, participants would have to hold in their working memory the number of males and females in a 20-image array and recognize the proportion perfectly accurately when recalling the information.

Post Hoc analyses on the one-way between subjects ANOVA revealed that the two highest sex ratios were not significantly different from one another, which this may support the ideas put forth by researchers dubious of frequency tracking theories. The underestimation of the higher frequencies may have led to the non-significant difference between the two conditions with the highest percentage (or frequency) of females. Some opponents of frequency tracking theory (see Zechmeister & Nyberg, 1982) have stated that low frequencies are *over* estimated and high frequencies are *underestimated* – these results demonstrate this trend (as seen in Table 6.1). This trend is in accordance with opponents of frequency tracking. While a linear relationship exists (and is strong), low frequencies are overestimated and high frequencies are underestimated. Given that encoding and recalling OSR information is theoretically supposed to serve as a way of choosing the optimal mating strategy in a given environment, the over and underestimation of the more extreme frequencies is troubling.

Overall Experiment 1 supported the hypothesis, and provided information suggesting that the sex ratio of a serially displayed array of novel individual faces is encoded through frequency of occurrence processing. As the frequency of females in each condition increased, estimates of the number of females increased linearly. This pattern is visually identical to the increase in estimations of word frequency in Hasher and Zacks' (1979) work. Further, because no instructions pertaining to frequency were given according to Hasher and Zacks' (1979), it is suggested that individuals encode sex ratio without attention, and that this process may very well be automatic.

Chapter 7 - Experiment 2 – Sex Ratio Encoding: OSR or ASR?

Operational Sex Ratio (OSR) has been linked to various behavioral changes (Dillon, Adair, & Brase, 2015; Durante et al, 2012; Emlen & Oring, 1977; Griskevicius et al., 2012; Hassinger & Kruger, 2013; Kruger & Schlemmer, 2009; Kruger & Vanas, 2012), and although the available literature has touched upon the importance of the difference between Operational Sex Ratio and Adult Sex Ratio, there is no available research pertaining to *which* sex ratio is actually encoded. It is of paramount importance to understand the encoding mechanism, as well as *which* sex ratio is being encoded, or if both are encoded, in order to make any inferences about the causal linkage between a population's OSR and behavior. Experiment 2 hypothesizes the following:

$H1_a$: Participants are encoding only one sex ratio, either Operational Sex Ratio or Adult Sex Ratio.

$H1_b$: Participants are encoding both Operational Sex Ratio *and* Adult Sex Ratio.

Experiment 2

Methods

Participants

Participants were recruited through the Kansas State University SONA subject pool. Two hundred and four participants made up the sample that was comprised of 46.1% male participants and 53.9% female participants. Participants' age range was 18-63 ($M = 21.99$, $SD = 6.26$). Due to the heteronormative nature of this work, only those data from self-reported heterosexuals were included.

Materials and Procedure

Similar to Experiment 1, Experiment 2 was performed online using Qualrics.com. Images of individuals were gathered from the NimStim Database (Tottenham et al., 2009) as well as the Parks Aging Faces Database (Minear & Park, 2004). For Experiment 2, unlike the stimuli chosen for Experiment 1, faces ranging in age from 18-70 were used; this was to ensure a portion of the faces in each sex ratio condition did not fit the criteria for Operational Sex Ratio, yet would fall under Adult Sex Ratio and vice versa.

After informed consent and demographics, participants were randomly assigned to one of five ASR/OSR conditions. These conditions all showed 20 faces, but each set of faces included some elderly individuals along with the previously used faces from Experiment 1 (see Table 7.1 for a breakdown).

After viewing 20 serially presented faces (and asked to estimated the age for each individual), participants were presented with the following question; "You just saw a series of faces. Please indicate the answer that best fits the proportion of sexes." This question was accompanied with a sliding scale (see Appendix B) with five anchors; "Entirely Male", "Mostly Male >75%", "Equal Males and Females", "Mostly Female, >75%", "Entirely Female." Again it is important to be aware that data provided from this question come out to a range of numbers from 0-100, and due to the location of the anchors, correct answers are for each condition are the percent of females in that condition.

In addition to the sliding scale, participants were presented with a hypothetical scenario (see Appendix C) wherein they were instructed to imagine themselves on a secluded island, stuck with only the people in the images they had just seen. Participants were given definitions for rivals, potential mates, and those to be excluded. Participants were then instructed; "Please give your best estimate below of the number of viable rivals relative to the number of viable mates. You will be answering in percentages - this means your numbers must add up to 100%. In other words, disregard the actual number of images, and give your best estimate for the percentages of males and females." Below this scenario/information were three text fields, one for Rivals (%), one for Mates (%), and one for Excluded (%). Participants who excluded any percentage were given the option of explaining who they excluded from the mating market and why in an open text field.

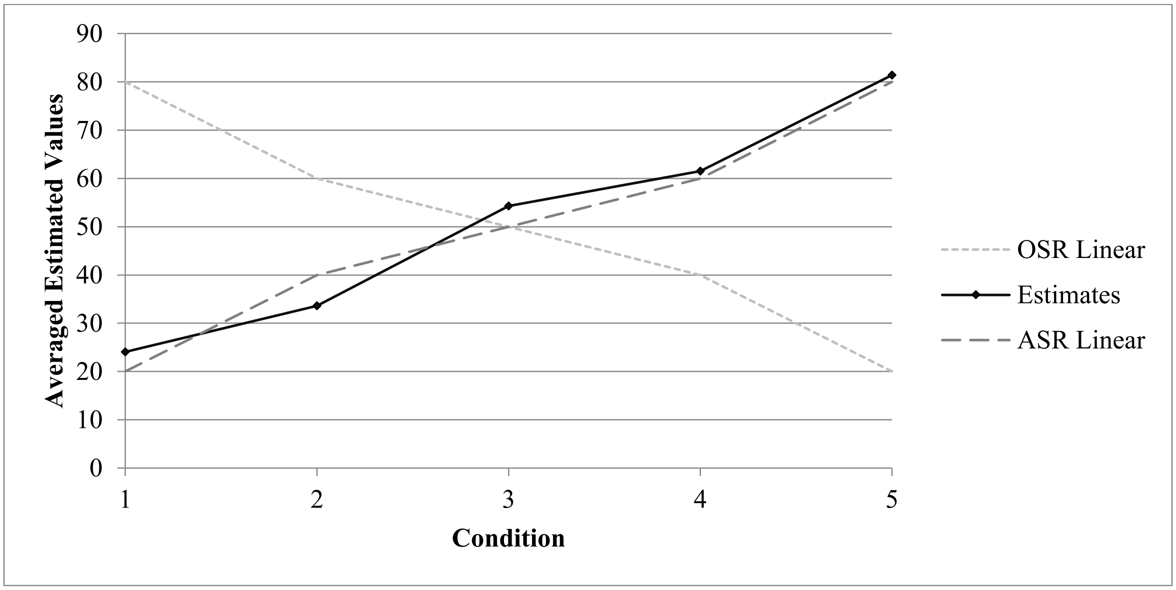
Table 7.1. Condition breakdown of Faces: Sex and Age Category

Condition		Male	Female	OSR	ASR
1	Young	1	4	80% Female, 20% Male	20% Female, 80% Male
	Old	15	0		
2	Young	4	6	60% Female, 40% Male	40% Female, 60% Male
	Old	8	2		
3	Young	5	5	50% Female, 50% Male	50% Female, 50% Male
	Old	5	5		
4	Young	6	4	40% Female, 60% Male	60% Female, 40% Male
	Old	2	8		
5	Young	4	1	20% Female, 80% Male	80% Female, 20% Male
	Old	0	15		

Results

Observed estimates positively correlated with Adult Sex Ratio (ASR); $r = .833$, $p < .001$, and negatively correlated with Operational Sex Ratio (OSR); $r = -.833$, $p < .001$. This inverse correlation is due to the nature of the conditional set up – ASR was always the opposite of OSR (see Table 7.1), this was done in order to effectively discriminate between ASR and OSR. In order to further explore the relationship between actual values for ASR and estimated values of overall sex ratio, means were taken for each of the five conditions (see Table 7.2, Figure 7.1). The means are similar to the ASR actual values, and increase as percentage of females in ASR increased (and percentage of females in OSR decreased). Moreover, the linear relationship between ASR values and estimated values (see Figure 7.1) shows that as the frequency of females in ASR conditions increased, as did estimated values. This suggests that ASR is what is recalled when asked for the relative proportion of males to females without any instructions regarding sex ratio criteria.

Figure 7.1. The Relationship Between Averaged Estimated Values and Actual Values



Note: The OSR and ASR linear relationships represented in Figure 7.1 are not straight because the difference between each condition was not consistent.

To further explore the relationship between ASR (actual) and estimated values, a one way between subjects ANOVA was run; $F(4, 211) = 134.99$, $p < .001$. A post hoc Tukey verified that each condition was significantly different from every other condition ($p < .05$). Additional support for the $H1_b$ comes from one sample *t*-tests for each ASR/OSR condition; for Condition 1; $t(45) = 2.837$, $p = .007$, for Condition 2; $t(40) = -3.60$, $p = .001$, for Condition 3; $t(40) = 1.42$, *p* = .163, for Condition 4; *t*(43) = .661, *p* = 512, and finally for Condition 5; *t*(43) = 1.03, *p* = .307 (for Means and Standard Deviations please see Table 7.2). These results demonstrate that the means for the first three conditions (with lower frequencies of females) were not significantly different from the actual proportion of Adult Sex Ratio (percent female). The last two conditions were significantly different which is most likely due to the large sample size – the means for conditions 4 and 5 show less than 2% difference from the actual values.

Table 7.2. Means and Standard Deviations of Estimated Sex Ratio by Condition

Condition	ASR	OSR	Mean	Standard Deviation
1	20% Female, 80% Male	80% Female, 20% Male	24.89	11.70
2	40% Female, 60% Male	60% Female, 40% Male	33.63	11.31
3	50% Female, 50% Male	50% Female, 50% Male	53.54	15.95
4	60% Female, 40% Male	40% Female, 60% Male	61.52	15.28
5	80% Female, 20% Male	20% Female, 80% Male	81.41	9.04

Hypothetical Mating Market Scenario

Using the numbers provided for mates and rivals, a percentage of females variable was created (to match the actual Adult Sex Ratio and Operational Sex Ratio, which are also based on percentage of females). Correlations among percent female in the mating market and percent female for ASR and OSR were run; for ASR; *r* = .017, *p* = .815, for OSR; *r* = -.017, *p* = .815 (see Table 7.3 for means and standard deviations). There was no significance for this variable – most likely this non-significant finding is due to participant confusion. Participants were given the option to give a text response for why they excluded whom, and many participants gave reasons indicating that they did not understand the objective of the question. Such comments include: “how am I supposed to say who I excluded, the images weren’t numbered”, “females, I'm heterosexual", and "everyone, they weren't my type." These comments suggested a lack of reading comprehension of the hypothetical island scenario.

Table 7.3. Means and Standard Deviations of Percent Female Estimate by Condition

Condition	ASR	OSR	Mean	Standard Deviation
1	20% Female, 80% Male	80% Female, 20% Male	49.73	27.02
2	40% Female, 60% Male	60% Female, 40% Male	46.27	19.52
3	50% Female, 50% Male	50% Female, 50% Male	48.91	17.82
4	60% Female, 40% Male	40% Female, 60% Male	49.81	24.04
5	80% Female, 20% Male	20% Female, 80% Male	49.85	25.51

Discussion

Experiment 2 results indicate that Adult Sex Ratio (ASR), rather than Operational Sex Ratio, is the sex ratio being encoded. The strong positive correlation provides support for $H1_b$. Additionally, unlike Experiment 1, conditions 3-5 did not have a statistically significant difference between estimated value means and the actual ASR value. Remarkably, this suggests that not only were participants sensitive to sex ratio, but their estimates were *so close* to the actual values that they were statistically indistinguishable. This combined with the lack of significance (or even a trend) for the OSR scenario strongly supports $H1_a$.

The post hoc analyses on the one way ANOVA revealed that each condition was significantly different from the others, which is interesting considering that the change in percent of females between each condition was not constant (e.g., between conditions 1 and 2 the change was 20%, whereas the change between 2 and 3 was only 10%). Experiment 2 supported $H1_a$ – ASR and OSR cannot be simultaneously encoded, and results indicated that ASR is encoded. It is possible that the wording of the sliding scale question ("Please indicate the answer the best fits the proportion of sexes") was too vague, leading participants to include all individuals in the array. If the question had been framed as a mating market question, different results may have emerged. Additionally, it may have been more difficult to assess percentages with an array of 20 images. A larger set size could eliminate this issue. Future work will benefit from a change in instruction.

Chapter 8 - Experiment 3 – Summary Statistics

Summary Statistics have been used to explore the automaticity and averaging of information from stimuli that is presented for a brief duration. In the current work, summary statistics are used to examine whether humans can extract sex ratio information from a briefly displayed image set of faces comprised of men and women. Further, Experiment 3 uses Summary Statistic methodology to determine whether the size of the set (e.g., 2x2, 2x4, and 3x4) affects the accuracy of performance. Set sizes were chosen based on the ability to display the sex ratio conditions (1.) 75% Female/25% Male, 2.) 50% Female/50% Male, and 3.) 75% Male/25% Female).

Pilot Study

A pilot study was run in order to assess whether or not sex ratios of briefly presented arrays (sets of faces) could be extracted as summary statistics. 10 participants were shown multiple 2x2 sets of faces with one of three sex ratios: 1.) 75% Female / 25% Male, 2.) 50% Female / 50% Male, and 3.) 25% Female / 25% Male). Participants saw each set for 330ms (the length of a single eye fixation), and then were presented with a multiple choice question asking participants to select the answer that best fit the proportion of the sexes seen in the set. There were only three choices for the question, matching up with the three conditions. Results indicated that participants did not perform much above chance (participants ranged in accuracy from 33% to 78% with a mean accuracy of 56%). All participants expressed complaints that the time duration was not sufficient, and they were guessing rather than making informed estimations.

Experiment 3

Though the majority of summary statistics research uses very small time durations for stimuli presentation (see Ariely, 2000; Ariely & Burbeck, 1995; Marchant, Simons, & de

Fockert, 2013), others such as de Fockert and Marchant (2008) used durations up to 3000ms even for simple stimuli (circles). Haberman and Whitney (2007) used longer durations for stimuli presentation due to the complexity of their facial stimuli. Combining this methodological information from summary statistics researchers with the pilot study participant feedback, it was decided that the current experiment would start with a duration speed of 1000ms. It was unknown whether 1000ms would be sufficient for sex ratio information to be extracted from various sized sets, due to the complexity and amount of information provided. It was decided that Experiment 3.a. would be run with a duration of 1000ms, and the experiment would be run again, separately (using a new group of participants), with the only difference being a duration of 330ms (Experiment 3.b.). This was done in order to establish the boundary conditions of the effect. If the results do not demonstrate a drastic decrease in performance from 1000ms to 330ms, this would suggest that the attention levels required to extract and process sex ratio information are at a bare minimum, i.e., are automatic.

Sample size was predetermined by the sample sizes of previous research on summary statistics. Ariely (2001) only used 2 participants, Chong and Treisman (2003) used only 5 participants, and Haberman and Whitney (2007) used 3 participants. However, these researchers were able to use more trials given their stimuli, whereas a set number of available faces were available for this experiment, and faces were not used more than once. Thus, sample sizes were to be between 30 and 50, with 45 trials for each participant. For Experiment 3, there are two basic competing hypotheses:

$H1_a$: Participants will be sensitive to the proportion of males to females in a given set, and will demonstrate this sensitivity with estimates similar to the correct (linear) proportions.

$H1_b$: Participants will not be sensitive to the proportion of males to females in a given set, their estimates will not suggest encoding of sex ratio information from briefly flashed images.

$H2_a$: Encoding of sex ratio information is automatic, therefore no difference should be seen between the results of 1000ms or 330ms, and estimates should remain stable across set size.

$H2_b$: Encoding of sex ratio requires attention, therefore those given 1000ms to look at a set should out-perform those given 330ms. Further, estimates should improve for smaller sets, and should decline for larger sets.

Experiment 3.a. (1000ms)

Methods

Participants

Participants were recruited using the Kansas State University SONA system, which is comprised of students enrolled in Introductory Psychology, as well as some upper level psychology classes. Participants were granted course credit for participating. Forty-one participants completed the experiment, the sample that was comprised of 31.7% male participants and 67.6% female participants. Participant age range was 18-42 (*M* = 20.12, *SD* = 4.19).

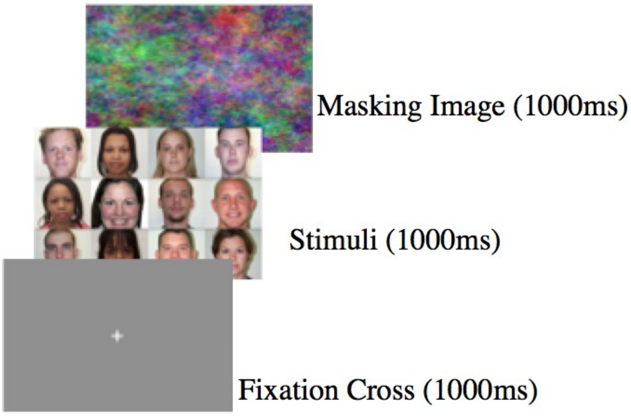
Materials and Procedure

Materials included two types of sets: practice trial sets (made up of images of cats and dogs) and actual trial sets (made up of images of males and female faces). Qualtrics.com was used to implement the experiment, however, the online research tool was used in person as to get rid of Internet connectivity differences, and research assistants cached every set in the browser before participants arrived, in order to ensure the image duration would be accurate.

Participants came into the lab, after informed consent was given and demographics were completed, took part in 18 practice trials and 40 actual trials. Practice trials used the same proportions and image durations as actual trials, but with dogs and cats as stimuli rather than males and females. The actual trials consisted of three different sized sets of faces (2x2, 2x4, 3x4) and three different Operational Sex Ratios (25% Female / 75% Male, 50% Female / 50% Male, 75% Female / 25% Male).

Each trial had a fixation point, where participants were instructed to focus on a cross and move on to the next page at their own pace once they were fixated on the cross. Sets were shown for 1000ms, followed by a masking image displayed for 1000ms (see Figure 8.1 for a trial schematic example). Finally, participants were presented with a sliding scale with five anchors (Entirely Male, Mostly Male (>75%), Equal Male and Female, Mostly Female (>75%), and Entirely Female). Instructions asked participants to estimate the proportion of males and females in the set they had just seen (see Appendix D for sliding scales). Materials were presented via qualtrics.com on computers at Kansas State University (See Appendix E for example materials, Figure 8.1 for Trial Schematic).

Figure 8.1. Trial Schematic for Experiment 3.a.



Results

Forty-eight students took part in Experiment 3.a., but data from participants who provided incomplete data were removed, leaving data from 41 participants. Supporting $H1_a$, participants were sensitive to sex ratio proportions – the data followed a linear trend, with means for each condition close to the actual value for that condition (see Table 8.1). A Pearson correlation of all expected and observed values (averaged across set size conditions) was significant and positive: $r = .85$, $p < .01$. Pearson correlations for each set size were run, examining the actual values with the estimated values (see Table 8.1, Figure 8.2). Means were examined for each set size condition as well as each sex ratio condition (see Table 8.2).

Table 8.1. Correlation between Actual and Estimated Values

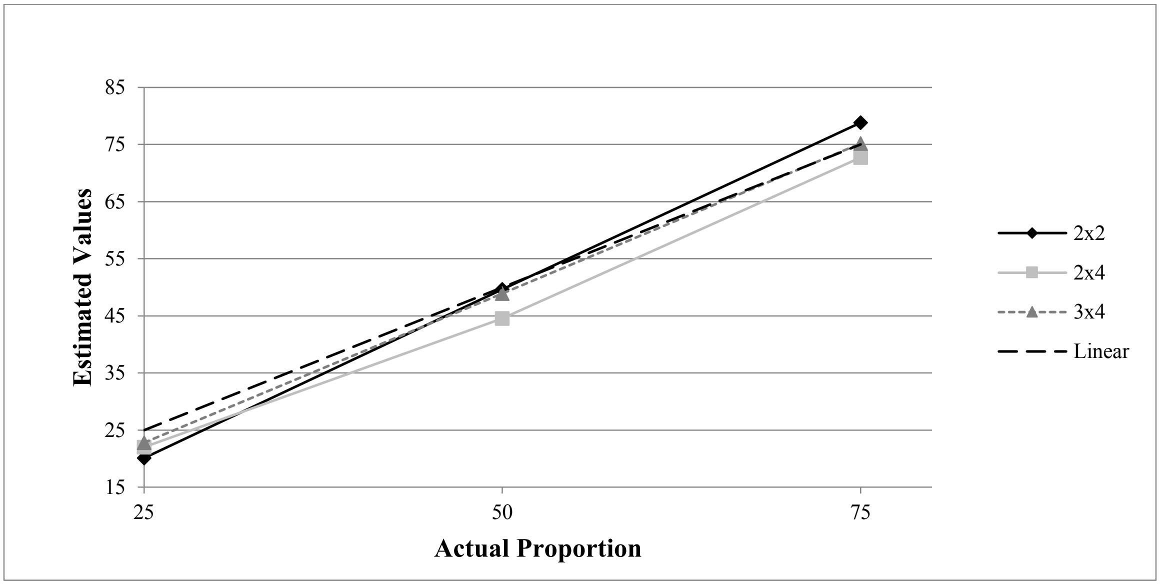
Pearson Correlation	2x2	2x4	3x4	Averaged
r	.926*	.815*	.807*	.850*

* $p < .01$

Table 8.2. Means and Standard Deviations for Each Condition by Each Set Size

		2x2	2x4	3x4	Averaged
25% Female / 75% Male	M	20.09	22.00	22.79	21.62
	SD	8.16	8.27	7.93	5.99
50% Female / 50% Male	M	49.66	44.56	48.89	47.70
	SD	3.50	5.63	8.21	3.42
75% Female / 25% Male	M	78.83	72.70	75.19	75.58
	SD	7.82	10.72	9.40	7.54

Figure 8.2. Proportion Estimates by Set Size – 1000ms duration



Pearson correlations between actual values (25, 50, 75) and estimated values were run for each set size: 2x2: $r = .926$, $p < .01$, 2x4: $r = .815$, $p < .01$, 3x4: $r = .807$, $p < .01$ (see Figure 8.2). A Fisher's r to z transformation was used to compare correlations for the set sizes: the correlation for 2x2 is significantly greater than 2x4, $z = 8.53$, $p < 0.001$, and 3x4, $z = 8.94$, $p < 0.001$. Finally, there was no significant difference between 2x4 and 3x4, $z = 0.41$, $p = 0.68$. This finding supports $H2_b$.

Discussion

Participants were able to estimate sex ratio proportions, estimates of which deviated only slightly from the actual values. This supports $H1_a$, suggesting that individuals and sex ratios do serve as stimuli that can be used in summary statistic research – that participants can view a set for a brief duration, and report with considerable accuracy the proportion of males to females. Because the Pearson Correlation Coefficient ranges from -1.0 to +1.0, these values can be interpreted as effect sizes. Cohen's standards for effect size denote that anything above .5 is considered "large." Correlations for each set size in this experiment were above .8, indicating large effects.

Correlations for each set size were compared using Fisher's r to z transformation, which demonstrated that the 2x2 correlation coefficient was significantly different (larger) than both the 2x4 and 3x4 correlations (which did not differ significantly from one another). Because the 2x2 correlation was significantly stronger than the others, the larger sets may require some attention to encode sex ratio from sets. These correlational differences may provide evidence that 2x2 (four faces) is the maximum amount of stimuli that can automatically be extracted and turned into a summary statistic. Had there been no significant difference among the three set size correlation coefficients, complete automaticity would certainly be implicated.

It was a concern that facial stimuli would be too complex for complete automatic extraction and summarization. It appears, rather, that it is the number of faces that decreases performance accuracy (i.e., requires attentional resources).

Experiment 3.b. 330ms

A second version of Experiment 3 was run with a single caveat: image duration.

Methods

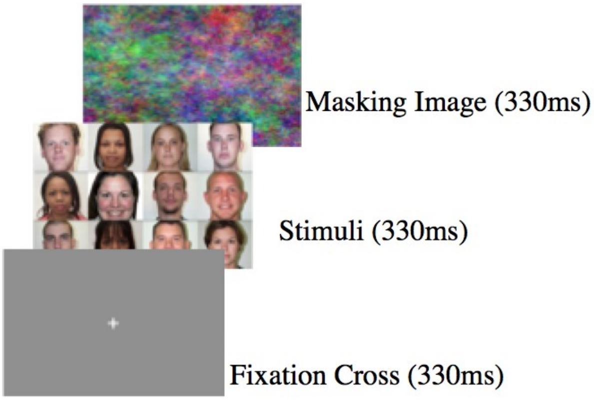
Participants

Participants were recruited using the Kansas State University SONA system, comprised of students enrolled in Introductory Psychology, as well as some upper level psychology classes. Participants were granted course credit for participating. Forty-nine participants completed the experiment, the sample that was comprised of 18.4% male participants and 81.6% female participants. Participant age range was 18-27 (*M* = 19.18, *SD* = 1.47).

Materials and Procedure

Materials were identical to Experiment 3.a., the only difference was the duration of stimuli in the procedure. Each trial had a fixation point, where participants were instructed to focus on a cross and move on to the next page at their own pace once they were fixated on the cross. Sets were shown for ***330ms***, followed by a masking image displayed for ***330ms***. Finally, participants were given a sliding scale with five anchors (Entirely Male, Mostly Male (>75%), Equal Male and Female, Mostly Female (>75%), and Entirely Female). Instructions asked participants to estimate the proportion of males and females in the set they had just seen (see Appendix D for sliding scales). Materials were presented via qualtrics.com on computers at Kansas State University (See Appendix E for example materials, Figure 8.3 for Trial Schematic).

Figure 8.3. Trial Schematic for 3.b.



Results

Fifty-one students took part in Experiment 3.b., data were cleaned, removing data from participants who did not finish the experiment, leaving data from a total of 49 participants. The data did not deviate from the linear line depicting the expected Operational Sex Ratio values. Pearson correlations for each set size were run, examining the actual values with the estimated values, for 2x2; $r = .909$, $p < .001$, 2x4; $r = .728$, $p < .001$, and 3x4; $r = .730$, $p < .001$ (see Figure 8.4). A Pearson correlation of all actual and expected values (averaged across conditions) was significant and positive: $r = .789$, $p <.01$. Fisher's r to z transformation was used to compare correlations for each set size. Again, the correlation for 2x2 was significantly greater than 2x4, $z = 11.83$, $p < 0.001$ and 3x4, $z = 11.34$, $p < 0.001$. Finally, there was no significant difference between 2x4 and 3x4, $z = 0.08$, $p = 0.647$. This indicates that the 2x2 sets had significantly higher correlations than the 2x4 and 3x4 – suggesting that four faces in a 2x2 set may be the most information that can be extracted completely automatically.

Figure 8.4. Proportion Estimates by Set Size – 330ms duration

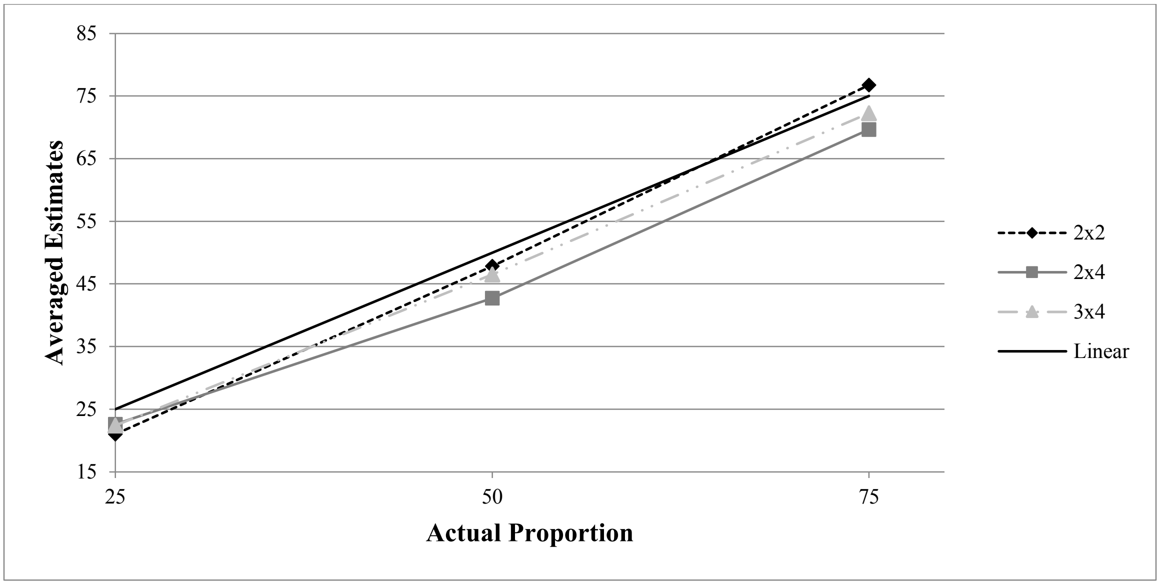


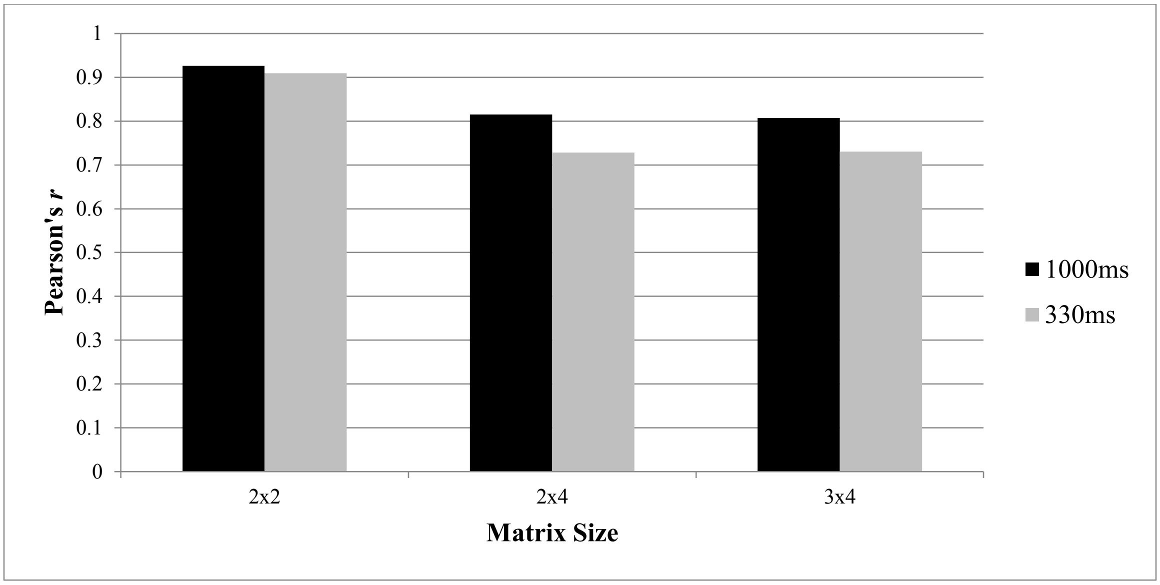
Table 8.3. Means and Standard Deviations for Each Condition and Each Set Size

		2x2	2x4	3x4	Averaged
25% Female / 75% Male	M	21.00	22.59	23.63	22.40
	SD	6.80	6.76	8.97	5.64
50% Female / 50% Male	M	47.83	42.71	49.34	46.49
	SD	4.84	8.81	7.26	4.63
75% Female / 25% Male	M	76.78	69.64	70.32	72.26
	SD	7.28	9.24	11.05	6.47

Comparing 1000ms to 330ms

Using Fisher's r to z transformation on the correlations for each set size between correlations from the 1000ms duration experiment, and correlations from the 330ms duration experiment. Significance emerged between correlations for the two durations for all set sizes, suggesting that there is a difference between the accuracy of the estimates for those who saw the sets for 1000ms versus those who saw the sets for 330ms. For the 2x2 set; $z = 1.97$, $p =. 024$, for the 2x4 set; $z = 3.89$, $p < .001$, for the 3x4 set; $z = 3.89$, $p < .001$. This finding supports $H2_b$ – the correlations for the 1000ms duration experiment were significantly greater than those for the 330ms duration experiment (see Figure 8.5). The implications of this finding will be addressed in the last chapter.

Figure 8.5. Pearson's *r* values for Actual and Estimated Values



Discussion

Perhaps the most compelling of all findings in the current work, the results of Experiment 3.b. provide the most credence to the prediction of automaticity in sex ratio encoding. 330ms is widely accepted as the length of a *single* eye fixation (Rayner, Li, Williams, Cave, & Well, 2007), as such, these findings demonstrate that within a single eye fixation, participants are able to extract and encode the relative sex ratio. It is important to note that the Pearson Correlation Coefficient demonstrating the relationship between actual and estimated proportions of sex ratio for the 2x2 set was *significantly* larger (stronger) than the coefficients for the other two set sizes. Due to the common accepted notion that 330ms is equal to a single eye fixation, this jump in correlation size is not surprising – it is possible (and easy, for some) to see four faces in a single eye fixation, whereas with the larger set sizes, one would have to make saccades in order to see each part of the set.

It is clear by both the charted means and the means themselves that individuals are fairly accurately estimating the proportion of males to females. Because the same effect (albeit slightly weaker) was found for the 330ms duration experiment as well as the 1000ms duration experiment, it is likely that despite the fact that this process may not be entirely automatic, very little attentional resources are necessary. The similarities in *r* values for 2x2 sets for both durations help to create the upper boundary of set size for automatic summary statistic extraction for stimuli as complex as faces.

Chapter 9 - Overall Discussion

Summary of Results

The aims of the current work were to explore the cognitive underpinnings of the encoding process of Operational Sex Ratio – in other words, is sex ratio processed automatically or effortfully, and if the latter, are the attentional resources required large or small? Aims included the exploration of whether or not Operational Sex Ratio is encoded over Adult Sex Ratio, which elucidates how interrelated the sex ratio that we encode is with those sex ratios specifically pertaining to mating.

Experiment 1 demonstrated that sex ratio is in fact a factor that can be tracked using frequency of occurrence methodology, supporting our hypothesis. A strong linear relationship was demonstrated, without prior knowledge about the point of the task, suggesting that the proportion of males to females is encoded with an absence of attention. It is worth noting that in Experiment 1, all estimates were significantly different from the condition's actual value, as determined by one-sample *t*-tests. This merely means that participants are not able to recall sex ratio with *complete* accuracy.

Originally it was expected that Operational Sex Ratio was the sex ratio that would be encoded, due to the large number of studies using Operational Sex Ratio as a variable that had implications for mating. Instead, it was found that Adult Sex Ratio is encoded and recalled from an array of faces. The mating market measure in Experiment 2 (where participants were given a hypothetical scenario and asked to estimate percentages of rivals, potential mates, and those excluded from the mating market) provided no significant findings, suggesting that ASR and OSR cannot be simultaneously encoded. Interestingly, when participants were provided with a text entry field to explain who they chose to exclude and why, many cited age or reproductive viability as a reason to exclude from the mating market. Some examples of those comments include; "Elderly women. There is such a high risk of birth defects. Not good for repopulation", "all men and women that seemed age of 40 and over. Because I do not see women over 40 as potential mate, nor I see men over 40 as rivals", and "All of them women that I estimated to be over 50 years old because they are no longer of child-bearing potential." This is intriguing, and could lead to future research where more explicit instructions are given, and participants are specifically asked for the OSR and ASR separately.

The methodology used in Experiment 3 was critical to this work. When testing any construct, it is useful and more valid to employ multiple methodologies. If results from different methodologies come to the same conclusion, the evidence becomes more robust. Further, summary statistics have led some researchers to believe that significant results suggest automaticity; Haberman and Whitney (2007) used summary statistic methodology to examine whether mean emotion could be extracted from a sets of faces, and when they found a rapid extraction of mean emotion, they postulated that an adaptive mechanism for merging/summarizing information into efficient chunks was in place. Following Haberman and Whitney's (2007) conclusions, the statistically compressed/averaged estimates of sex ratio from briefly presented sets of faces could suggest that there is an adaptive mechanism at work that extracts the necessary information from a larger group of individual items.

Summary statistics of briefly displayed sets of faces of males and females were encoded for set sizes from 4 (2x2) to 12 (3x4) faces. Strong correlations were found across all set sizes for durations of both 1000ms and 330ms. Sex ratio was extracted from sets of faces after being presented with them for a miniscule amount of time, suggesting there is automaticity to the process. For both time durations, it was discovered that the smallest set size had significantly stronger correlations than the two larger set sizes, which were not significant different from one another. This finding begins to help create boundaries for set size and the encoding of sex ratio. Because the 2x2 set size was significantly different (i.e., had stronger correlations) for both duration times, it is believed that 2x2 may be the upper boundary limit in how large a set size can be where sex ratio information can still be extracted and recalled as a summary statistic.

Implications

None of the experiments in the current work informed participants of the point of the studies – in other words, no participants were informed of the sex proportion information, yet results demonstrated that participants were able to extract, encode, and recall that information with fairly good accuracy. Automatic processes are important for daily life; if humans had to devote attention to every aspect of the environment it would be rather difficult to get anything done. It is hard enough to choose the right mate without having to stretch our working memory capacity to help make a decision regarding the best strategy for a given population.

More extreme sex ratios (very female-biased or very male-biased) are not particularly common. A possible critique of this work would be that these vastly unequal sex ratios (such as 4:1) are unlikely to occur in the real world. However, Watkins, Jones, Little, DeBruine, and Feinberg (2012) used ratios as unequal as 5:1, and found similarities between these unequal sex ratios and possible real-life social gatherings. Watkins et al. (2012) therefore came to the conclusion that the unequal sex ratios used in sex ratio research are not unrealistic, and thus do not violate ecological validity.

Because sex ratios were manipulated in this work, and participants only saw each face or set of faces once, it is clear that knowledge of sex ratio via extraction and encoding is fluid – people encode it from manipulated arrays with good accuracy, suggesting that sex ratio information would be detected in novel environments. If sex ratio encoding is fluid, then it is more reasonable to see sex ratio as a predictor for behavioral changes. In other words, if one moved from an area with a relatively equal sex ratio to an area mostly populated with their own sex, this information would replace the equitable sex ratio information, and thus may support the notion that sex ratio changes mating behavior and strategies. To take this one step further, biased sex ratios create different mating strategies for the scarcer versus the more abundant sex, and picking up this information automatically when moving to a new place would help an individual make mating and reproductive decisions that fit best with their environment (of rivals and potential mates).

A *single* eye fixation was found to encode accurate information. People seem to be very adept at picking up sex ratio information – understanding the boundaries of how many in a set signify the boundaries of durations for our ability to encode information may help us to better understand mating strategy choices in real life – at social gatherings such as bars or parties. The fact that strong correlations were found between actual sex proportion and estimated sex proportion for all set sizes is an important finding – it suggests that humans do not have to fixate individually on each item in a set in order to get the basic understanding of the sex ratio. This can be useful for understanding a litany of other complex stimuli – if one does not have to fixate individually on each item in any sort of set, the summary information can be encoded from a peripheral visual standpoint.

The absence of attention suggests automaticity, which implies that encoding sex ratio is like reading; it happens whether we want it to or not. This could create problems within partnerships, it may increase jealousy, which can lead to intimate partner violence (Babcock, Costa, Green, & Eckhardt, 2004). Automaticity implications from the current work provide credence to the prior research conducted on sex ratio as a predictor variable.

Limitations

The experiments in the current work did not require participants to give any information regarding ethnicity. Due to the multi-ethnic diversity within the facial databases it is possible that race may have been a distracting or confounding factor in Experiments 1 and 2, in which individual faces were presented serially. Cross-racial identification is known to be more limited (Hugenberg, Miller, & Claypool, 2007), and this may also affect the extracting of sex ratio. Another limitation for the current work is that the facial databases (Tottenham, et al., 2009; Minear & Park, 2004) used for stimuli did not provide actual ages for individuals pictured, and thus there is no way to determine whether individuals were giving accurate estimations when giving the age of each individual presented. However, age estimation was used as a precautionary measure, and was not specifically analyzed, indicating age estimate limitations are of little relevance.

The sliding scale measure used as the dependent variable across all experiments may have served as an issue in the current work. Participants were giving their estimates of percentage of females rather than an actual ratio. More specific sex ratio anchors could improve estimations.

Experiment 1 had a disproportionate number of male and female participants (36.9% male and 63.1% female), which could be considered a limitation if one sex was more accurate at estimating sex ratios. There is no evidence for this, however: : male and female estimates of sex ratio were not significantly different from one another (as demonstrated using independent samples *t*-tests): condition 1; $t(35) = -.624$, $p = .534$ (Male $M = 20.50$, $SD = 6.33$, Female $M =$

21.72, *SD* =5.18), for condition 2; *t*(36) = .235, *p* = .816 (Male *M* = 34.78, *SD* = 7.60, Female *M* = 34.15, *SD* = 8.77), for condition 3; *t*(38) = 1.63, *p* = (Male *M* = 50.07, *SD* = 10.34, Female *M* = 44.47, *SD* = 10.27), for condition 4; *t*(35) = -.925, *p* = .361 (Male *M* = 64.13, *SD* = 7.32, Female *M* = 67.56, *SD* = 9.71), and for condition 5; *t*(33) = .035, *p* = .972 (Male *M* = 70.82, *SD* = 9.19, Female *M* = 70.72, *SD* = 7.90).

Conditions for Experiment 2 were carefully arranged in order to get inverse proportions of OSR and ASR for each condition. However, because of the limitations that the inverse sex ratio require in some conditions (see Table 7.1) there were no reproductively viable individuals of one sex – this may have been a confounding factor and may have led to an increase in overall (adult) sex ratio extracting if the opposite sex of the participant was not represented within their mating age group. Participants may not have seen the array in terms of a mating market if there were no acceptable potential mates displayed in the array of their condition. Larger arrays could potentially fix this in future studies.

The availability heuristic could have been a confounding influence on estimates of sex ratio, particularly on a college campus where Greek life is common. For instance, if female participants had participated in the study right after a sorority meeting, or if male participants had participated right after a fraternity meeting, their estimates of the frequency of their own sex might be *over*estimated due to the availability of females in a sorority member's working memory or the availability of males in a fraternity member's working memory.

Results from Experiment one showed a trend of overestimating low frequencies and underestimating higher frequencies (a critique of frequency of occurrence tracking put forth by Zechmeister and Nyberg, 1982). One possible explanation for this finding is that there is the same homeostatic pressure to return to a sex ratio of 1:1 as described by Fisher (1930). Although

Fisher's explanation of this pressure was on a population level, not an individual level, because biased sex ratios are less common than equitable sex ratios, it is possible that people tend to regress toward the (more equitable) sex ratio of the general population.

Strengths

The age estimation requirement in Experiments 1 and 2 may have served as a second task, which would make the experiments fall under the category of dual task paradigms. VanRullen, Reddy and Koch (2004) and Reddy, Wilken and Koch (2004) examined attentional restraints and boundaries by using a dual task paradigm in their research. A dual task paradigm involves subjecting participants to two tasks at once, to determine whether their performance is hindered by the addition of a second task (often dual task results are compared to single task results). Due to the knowledge that dual task paradigms can demonstrate automaticity if accuracy does not decrease, this accident may have been incredibly useful. The mean ages of Experiment 1; 20.86 (*SD* = 3.79), and Experiment 2; 21.99 (*SD* = 6.26) are well within the reproductively viable age-range. As a result, all participants would be categorized into a single mating market, which suggests that the findings were not a byproduct of age differences.

Experiments 3.a. and 3.b. found little difference in accuracy between duration length of stimuli presentation (despite a significant difference, the correlations were all strong and fairly similar). Pearson Correlation Coefficients can be used as effect sizes due to their range of -1 to +1, and Cohen's guidelines for effect sizes are .1 for a small effect, .3 for a medium effect, and .5 for a large effect. Every correlation in both Experiments 3.a. and 3.b. fell into the large effect size category. Despite differences across set sizes duration length, the Pearson correlations for the 2x2 set size in 3.a. and 3.b. were larger than .9. This large effect size was also seen in

Experiment 1, which had an *r* value was larger than .9 and Experiment 2, which had an *r* value of larger than .8.

Following the results provided by both Hasher and Zacks (1979) lexical frequency encoding experiment and Experiment 1's pilot studies, the current work did not include informed and uninformed conditions; all participants were *uninformed* of dependent variable, and thus were not specifically attending to (or at least not being told to attend to) sex ratio as they viewed arrays of images (in Experiments 1 and 2), thus any encoding of sex ratio was done without specifically attending to that information. Experiments 3.a and 3.b were also uninformed, though due to the nature of the procedure (numerous trials), it is likely that participants became informed within a few trials. Participants encoded and recalled sex ratio with no prior instructions to do so, which suggests automaticity across experiments. To further elucidate the notion of automaticity, the sex ratio in sets as large as 12 faces could be extracted moderately accurately within a *single* eye fixation.

Future Directions

The abundance of significance demonstrated in the four experiments completed only serves to increase interest in the area – a foundation has been created which will lead to a lengthy research program. Future directions stemming from the current work cross various sections of research.

An experiment wherein participants were given both the frequency of identity occurrence stimuli from Experiment 1 (Pilot 1) as well as reproductively viable and elderly individuals as stimuli would increase collective knowledge regarding human ability in recognizing and tracking specific individuals as well as human ability to track sex ratio. If a mating market scenario was created, it would be interesting to examine the ways in which older adults are included or excluded.

Priming is a fascinating aspect of cognitive psychology that was not employed in the current work, but should be addressed in future research. One methodological change to the existing Experiment 2 would be to have the mating market hypothetical scenario information about the secluded island presented before the array of faces – if participants are primed to think about mating markets and strategies, an array of younger and older people may be tracked using only those reproductively viable (coinciding with the OSR side of the condition) rather than the total proportion of the sexes (which was found to coincide with ASR). To expand on the idea of using the hypothetical scenario as a primer, instead of asking participants to list percentages of rivals, potential mates, and those to be excluded from the mating market *after* viewing an array of images, each image could have a multiple choice question wherein participants would categorize the individual in the image as a rival, potential mate, or someone to be excluded from the mating market. The scenario would function as a primer, while the multiple choice questions would allow participants to create their mating market as they go, instead of post hoc. Additionally, qualitative data could be taken for each face – why the person was excluded, etc., which would provide far more information about exclusions from mating markets. One might question what the "proper" mating strategy for a given context is. Following the line of reasoning put forth by Dawkins (1976) (among numerous others), we exist merely to pass on our genetic material, thus the proper mating strategy for a given context would be one that results in reproduction. Therefore, a female in a male-biased sex ratio should adjust her strategies to pick the best male, as she has an assortment to choose from, whereas a female in a female-biased sex ratio should adjust her strategy by lowering expectations and behaving more in terms of short-term mating goals.

The faces chosen for stimuli in the current work had previously been rated as average in terms of attractiveness. This was done for two reasons: 1.) a lot of variability in attractiveness would probably lead to the exclusion of perfectly acceptable potential mates, and 2.) it has been shown that people attend more to individuals they find physically attractive (Lorenzo, Biesanz, & Human, 2010), and the face databases (Tottenham, et al., 2009; Minear & Park, 2004) did not include enough highly attractive people to create the sets. However, it seems from qualitative data gathered from Experiment 2's "who did you exclude and why" textbox, that many people were excluding individuals based on a lack of physical attraction. If Experiment 2's stimuli could be replicated with individuals who have previously been rated as high on attractiveness, results may match up better with age, providing more information as to whether older adults are excluded from mating markets.

In order to further examine whether sex ratio is a predictor for choice of mating strategies, future studies could replicate Experiment 1, with the very important addition of a series of dependent variables asking participants various decision-making questions that would demonstrate specific mating strategy choices. The adaptive problem that the encoding of sex ratio could conceivably solve is the issue of choosing a mating strategy that contextually fits a given environment. This would add to the growing evidence suggesting that sex ratio serves as a predictor for mating strategies.

In conclusion, this work establishes that there is automaticity in processing of sex ratio. This was demonstrated through frequency tracking methodology wherein participants are uninformed of the purpose of viewing the serially displayed array of images and thus do not purposely attend to sex ratios while viewing the array, and through summary statistic methodology, where accurate information regarding proportions of males and females in a given set was extracted, encoded, and recalled after a brief duration of stimulus presentation, even at a duration the length of a *single* eye fixation. The automaticity of encoding information regarding proportion of sexes, *especially* from a single eye fixation, has implications for the human ability to change mating strategies depending on the population sex ratio of one's current environment without attending to the males and females in the area purposefully or effortfully. Reproductive fitness should increase if choosing a mating strategy requires little to no deliberate attention. This work has established an incredibly low level of attention for some sex ratio encoding and automaticity for others – boundaries for level of automaticity were established. This work has implications related to evolution, mating, and working memory (via eye fixation) – the foundational aspects created here could serve as groundwork for a lifetime's worth of research.

References

Ariely, D. (2001). Seeing sets: Representation by statistical properties. *Psychological Science, 12*(2), 157-162.

Ariely, D., & Burbeck, C. A. (1995). Statistical encoding of multiple stimuli: a theory of distributed representation. *Investigative Ophthalmology and Visual Science, 36*(4), 8472.

Babcock, J. C., Costa, D. M., Green, C. E., & Eckhardt, C. I. (2004). What situations induce intimate partner violence? A reliability and validity study of the Proximal Antecedents to Violent Episodes (PAVE) scale. *Journal of Family Psychology*, *18*(3), 433.

Baddeley, A. (1992). Working memory. *Science*, *255*(5044), 556-559.

Bem, S. L. (1981). Gender schema theory: A cognitive account of sex typing. *Psychological Review*, *88*(4), 354.

Brown, N. R. (2002). Encoding, representing, and estimating event frequencies: A multiple strategy perspective. In P. Sedlmeier & T. Betsch (Eds.), *Frequency Processing and Cognition* (pp. 37-53). Oxford: Oxford University Press.

Buss, D. M. (2012). *Evolutionary Psychology: The new science of the mind, 4th Edition*. Allyn & Bacon: Boston, MA.

Buss, D. M. (1989). Sex differences in human mate preferences: Evolutionary hypotheses tested in 37 cultures. *Behavioral and Brain Sciences*, *12*(01), 1-14.

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision Research, 51*(13), 1484-1525.

Chong, S. C., & Treisman, A. (2003). Representation of statistical properties. *Vision Research*, *43*(4), 393-404.

Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans reason? Studies with the Wason selection task. *Cognition*, *31*(3), 187-276.

Cowan, N. (2010). The magical mystery four: How is working memory capacity limited, and why? *Current Directions in Psychological Science, 19*(1), 51-57.

Cowan, N. (2000). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*(1), 87-185.

Darwin, C. (1859). *The origin of species.* London: Penguin.

Dawkins, R. (1976). *The selfish gene.* New York: Oxford University Press.

de Fockert, J., & Wolfenstein, C. (2009). Rapid extraction of mean identity from sets of faces. *The Quarterly Journal of Experimental Psychology*, *62*(9), 1716-1722.

de Fockert, J. W., & Marchant, A. P. (2008). Attention modulates set representation by statistical properties. *Perception & Psychophysics*, *70*(5), 789-794.

Del Giudice, M. (2012). Sex ratio dynamics and fluctuating selection on personality. *Journal of Theoretical Biology*, *297*, 48-60.

Dillon, H. M., Adair, L. E., & Brase, G. L. (2015). Operational Sex Ratio and Female Competition: When there aren't enough fish in the sea. In Fisher, M. (Ed.), *Oxford Handbook of Female Competition*, Oxford University Press.

Durante, K. M., Griskevicius, V., Simpson, J. A., Cantú, S. M., & Tybur, J. M. (2012). Sex ratio and women's career choice: Does a scarcity of men lead women to choose briefcase over baby? *Journal of Personality and Social Psychology, 103*(1), 121-134.

Emlen, S. T., & Oring, L. W. (1977). Ecology, sexual selection, and the evolution of mating systems. *Science*, *197*(4300), 215-223.

Estimates of population and its percentage distribution, by age and sex and sex ratio for all ages for the world, major areas and regions. (2006). *United Nations Statistics Division* [data file]. Retrieved from: http://unstats.un.org/unsd/demographic/products/dyb/dyb2006/Table02.pdf.

Factbook, C. I. A. (2010). The world factbook. Retrieved from: *https://www. cia. gov/library/publications/the-world-factbook.*

Fisher, R. A. (1930). *The Genetical Theory of Natural Selection*. Clarendon Press, Oxford.

Greene, R. L. (1992). *Human memory: Paradigms and paradoxes*. Hillsdale, NJ: Erlbaum

Griskevicius, V., Tybur, J. M., Ackerman, J. M., Delton, A. W., Robertson, T. E., & White, A. E. (2012). The financial consequences of too many men: Sex ratio effects on saving, borrowing, and spending. *Journal of Personality and Social Psychology, 102*(1), 69 80.

Haberman, J., & Whitney, D. (2007). Rapid extraction of mean emotion and gender from sets of faces. *Current Biology*, *17*(17), R751-R753.

Haberstroh, S., & Betsch, T. (2002). Online strategies versus memory-based strategies in frequency estimation. In P. Sedlmeier & T. Betsch (Eds.), *Frequency Processing and Cognition* (pp. 205–220). Oxford: Oxford University Press.

Hamilton, W. D. (1967). Extraordinary sex ratios. *Science, 156*(3774), 477-488.

Hasher, L., & Zacks, R. T. (1984). Automatic processing of fundamental information: the case of frequency of occurrence. *American Psychologist*, *39*(12), 1372.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General*, *108*(3), 356.

Hassinger, B.E., & Kruger, D. J. (2013). The polygyny paradox: Several male biased populations exhibit a high prevalence of polygyny. *Journal of the Evolutionary Studies Consortium, 5*(2), 131-137.

Hintzman, D. L. (1976). Repetition and memory. In G.H. Bower (Ed.) *The Psychology of Learning and Motivation,* vol. 10 (pp. 47-91). New York: Academic Press.

Hugenberg, K., Miller, J., & Claypool, H. M. (2007). Categorization and individuation in the cross-race recognition deficit: Toward a solution to an insidious problem. *Journal of Experimental Social Psychology*, *43*(2), 334-340.

James, W. (1890). *The Principles of Psychology*. New York: Holt.

Kirsner, B. R., Figueredo, A. J., & Jacobs, W. J. (2003). Self, friends, and lovers: Structural relations among Beck Depression Inventory scores and perceived mate values. *Journal of Affective Disorders, 75*(2), 131–148.

Kokko, H., & Jennions, M. D. (2008). Parental investment, sexual selection and sex ratios. *Journal of Evolutionary Biology*, *21*(4), 919-948.

Kokko, H., & Johnstone, R. A. (2002). Why is mutual mate choice not the norm? Operational sex ratios, sex roles and the evolution of sexually dimorphic and monomorphic signaling. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *357*(1419), 319-330.

Kruger, D. J., & Schlemmer, E. (2009). When men are scarce, good men are even harder to find: Life history, the sex ratio, and the proportion of men married. *Journal of Social, Evolutionary, and Cultural Psychology*, *3*(2), 93-104.

Kruger, D. J., & Vanas, S. B. (2012). Local scarcity of women predicts higher fertility among married couples and more single father households. *Letters on Evolutionary Behavioral Science, 3*(2)*,* 17-20.

Kvarnemo, C., & Ahnesjo, I. (1996). The dynamics of operational sex ratios and competition for mates. *Trends in Ecology & Evolution, 11*(10), 404-408.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention and cognitive control. *Journal of Experimental Psychology: General*, *133*(3), 339.

Lorenzo, G. L., Biesanz, J. C., & Human, L. J. (2010). What Is Beautiful Is Good and More Accurately Understood Physical Attractiveness and Accuracy in First Impressions of Personality. *Psychological Science*, *21*(12), 1777-1782.

Lurye, L. E., Zoslus, K. M., & Ruble, D. N. (2008). Gender identity and adjustment: Understanding the impact of individual and normative differences in sex typing. *New Directions in Adolescent Development, 2008*(120), 31-46.

Macrae, C. N., & Bodenhausen, G. V. (2000). Social cognition: Thinking categorically about others. *Annual Review of Psychology*, *51*(1), 93-120.

Marchant, A. P., Simons, D. J., & de Fockert, J. W. (2013). Ensemble representations: Effects of set size and item heterogeneity on average size perception. *Acta Psychologica, 142*(2), 245-250.

Marlowe, F. W., & Berbesque, J. C. (2012). The human operational sex ratio: effects of marriage, concealed ovulation, and menopause on mate competition. *Journal of Human Evolution*, *63*(6), 834-842.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81-97.

Minear, M., & Park, D.C. (2004). A lifespan database of adult facial stimuli. *Behavior Research Methods, Instruments, & Computers. 36*(4), 630-633.

Noë, R., & Hammerstein, P. (1994). Biological markets: supply and demand determine the effect of partner choice in cooperation, mutualism, and mating. *Behavioral Ecology and Sociobiology, 35*(1), 1-11.

Pollet, T. V., & Nettle, D. (2008). Driving a hard bargain: Sex ratio and male marriage success in a historical US population. *Biology Letters, 4*(1), 31-33.

Rayner, K., Li, X., Williams, C. C., Cave, K. R., & Well, A. D. (2007). Eye Movements during Information Processing Tasks: Individual Differences and Cultural Effects. *Vision Research*, *47*(21), 2714–2726.

Reddy, L., Wilken, P., & Koch, C. (2004). Face-gender discrimination is possible in the near-absence of attention. *Journal of Vision*, *4*(2), 106-117.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance, 3*(1), 1-17.

Schmitt, D. P. (2005a). Sociosexuality from Argentina to Zimbabwe: A 48-nation study of sex, culture, and strategies of human mating. *Behavioral and Brain Sciences*, *28*(2), 247–275.

Schmitt, D. P. (2005b). Fundamentals of human mating strategies. In Buss, D. (Ed.) *The Handbook of evolutionary psychology* (p. 258-291). Wiley and Sons, Hoboken: NJ.

Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological Review*, *84*(2), 127.

Simpson, J. A., & Gangestad, S. W. (1991). Individual differences in sociosexuality: Evidence for convergent and discriminant validity. *Journal of Personality and Social Psychology, 60*(6), 870-883.

Stone, E. A., Shackelford, T. K., & Buss, D. M. (2007). Sex ratio and mate preferences: a cross-cultural investigation. *European Journal of Social Psychology*, *37*(2), 288-296.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643-662.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, *4*(4), 295-312.

Tooby, J., & Cosmides, L. (2005) Conceptual foundations of evolutionary psychology. In Buss, D. (Ed.) *The Handbook of evolutionary psychology* (p. 5-67). Wiley and Sons, Hoboken: NJ.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97-136.

Trivers, R. L. (1972). Parental investment and sexual selection. In B. Campbell (Ed.), *Sexual selection and the descent of man, 1871-1971,* (pp. 136-179). Chicago: Aldine.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157)*,* 1124–1131.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, *5*(2), 207-232.

VanRullen, R., Reddy, L., & Koch, C. (2004). Visual search and dual tasks reveal two distinct attentional resources. *Journal of Cognitive Neuroscience, 16*(1), 4-14

Watkins, C. D., Jones, B. C., Little, A. C., DeBruine, L. M., & Feinberg, D. R. (2012). Cues to the sex ratio of the local population influence women's preferences for facial symmetry. *Animal Behaviour, 83*(2), 545-553.

Werren, J. H. (1983). Sex ratio evolution under local mate competition in a parasitic wasp. *Evolution, 37*(1), 116–124.

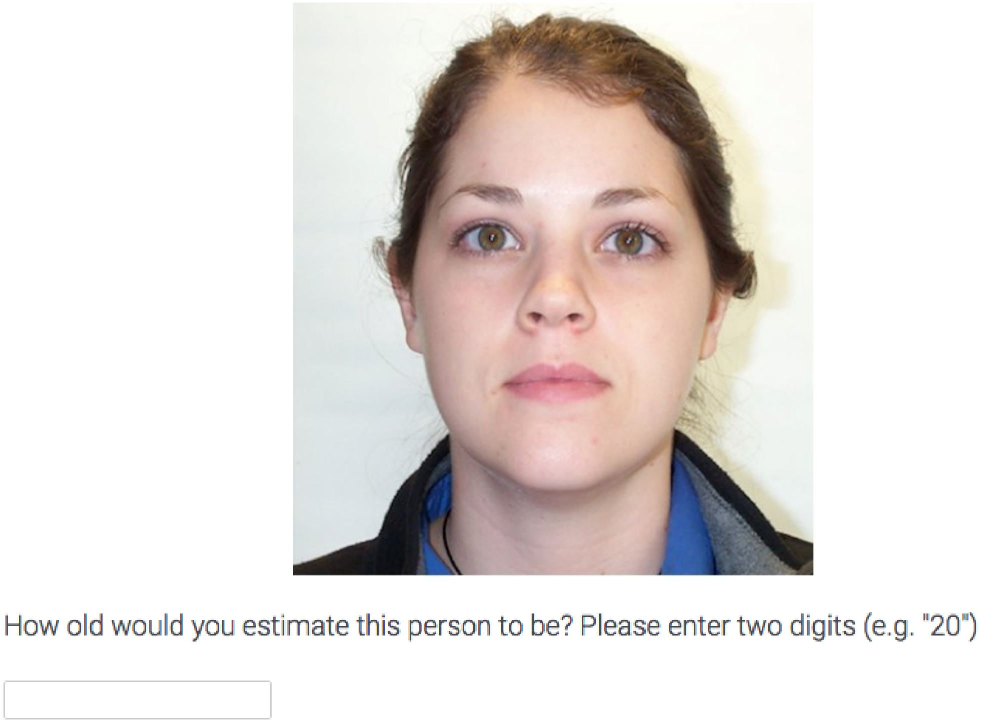
Williams, G. C. (1966). *Adaptation and natural selection: A critique of some current evolutionary thought.* Princeton, NJ: Princeton University Press.

Wilson, D. S., & Colwell, R. K. (1981). Evolution of sex ratio in structured demes. *Evolution, 35*(5), 882-897.

Zacks, R. T., & Hasher, L. (2002). Frequency processing: A twenty-five year perspective. In P. Sedlmeier & T. Betsch (Eds.), *Frequency Processing and Cognition* (pp. 21–36). Oxford: Oxford University Press.

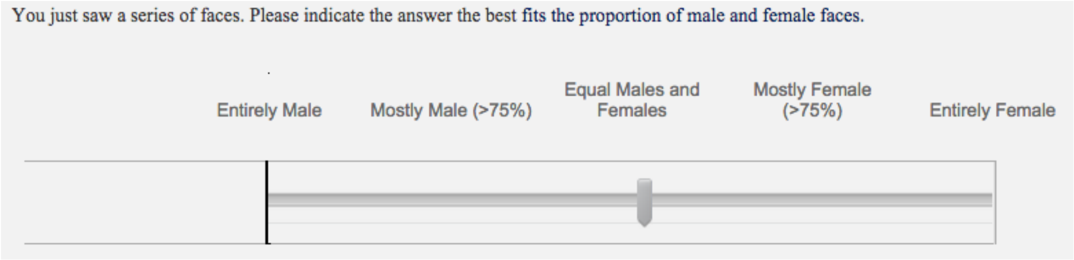
Zechmeister, E. B., & Nyberg, S. E. (1982) *Human memory: An introduction to research and theory.* Monterey, CA: Brooks/Cole Publishing Co.

Appendix A - Example Procedure for Experiment 1



How old would you estimate this person to be? Please enter two digits (e.g. "20")

Appendix B - Sliding Scale used for Experiments 1 and 2



You just saw a series of faces. Please indicate the answer the best fits the proportion of male and female faces.

Appendix C - Hypothetical Mating Market Scenario

(For Males)

The following is a hypothetical scenario you will use to answer the next question.

You are in an isolated area with only the people from the images you just viewed. There is no way to leave this area (for the foreseeable future) and no new people will be coming into this area. You have food, you have shelter, and overall life is acceptable.

In this situation, the people from the images you just viewed make up a “mating market”. That is, these are the people that you get to choose from in terms of relationship partners, and these are also the people you are competing against for relationship partners.

There are three categories that these people fall into:

Rivals = the males from the group of images who also could potentially mate with the females

Mates = the females from the group of images who you could potentially mate with.

Excluded = Not everyone may be a mate or a competitor. Ask yourself whether any members of the group should be definitively excluded from your estimation of potential mates and potential rivals.

(For Females)

The following is a hypothetical scenario you will use to answer the next question.

You are in an isolated area with only the people from the images you just viewed. There is no way to leave this area (for the foreseeable future) and no new people will be coming into this area. You have food, you have shelter, and overall life is acceptable.

In this situation, the people from the images you just viewed make up a “mating market”. That is, these are the people that you get to choose from in terms of relationship partners, and these are also the people you are competing against for relationship partners.

There are three categories that these people fall into:

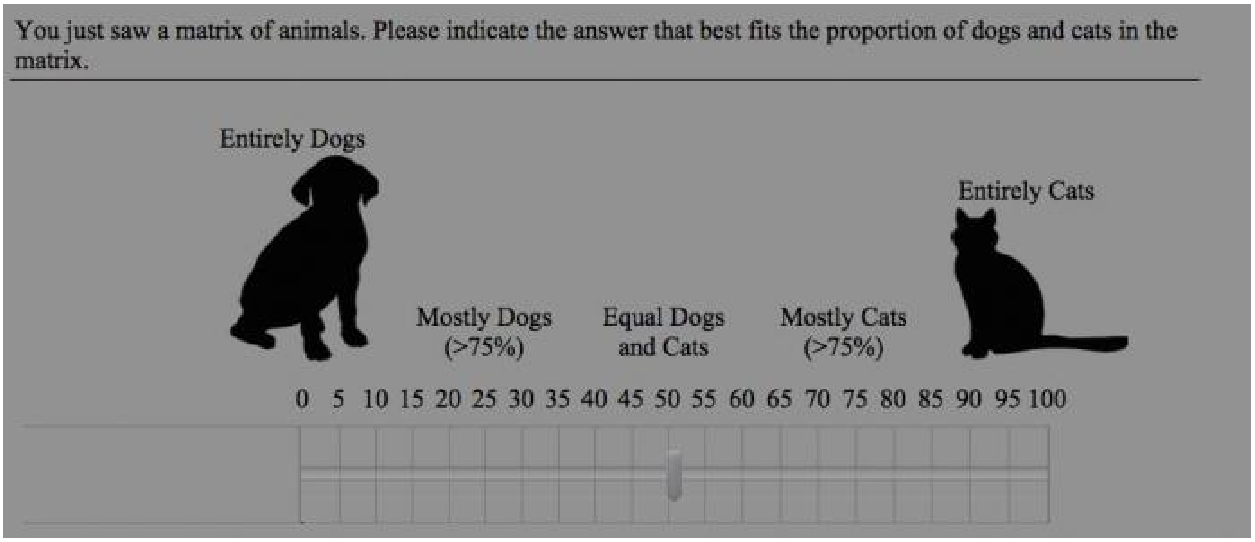
Rivals = the females from the group of images who also could potentially mate with the males

Mates = the males from the group of images who you could potentially mate with.

Excluded = Not everyone may be a mate or a competitor. Ask yourself whether any members of the group should be definitively excluded from your estimation of potential mates and potential rivals.

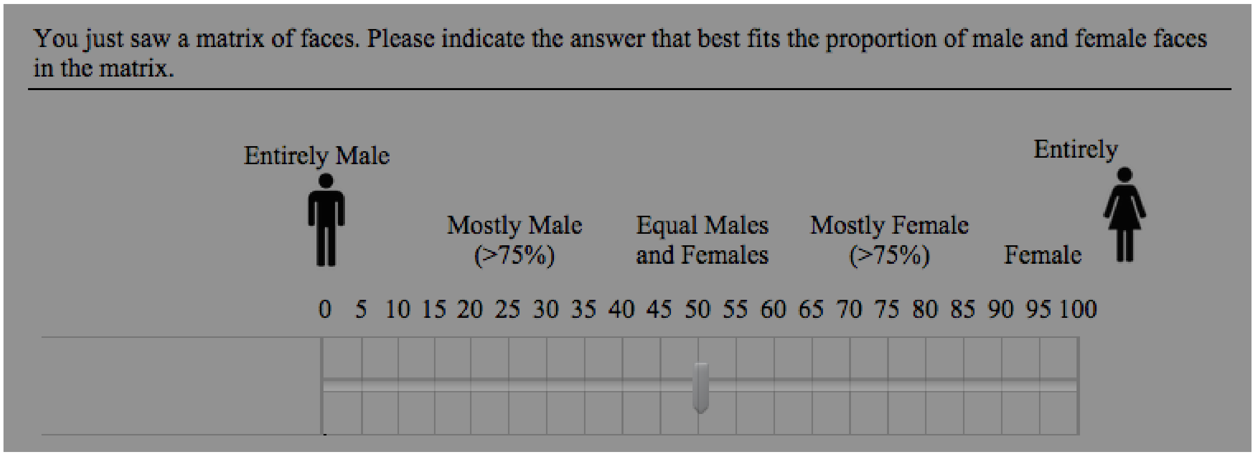
Appendix D - Sliding Scales for Experiment 3

Sliding scale for practice trials:



You just saw a matrix of animals. Please indicate the answer that best fits the proportion of dogs and cats in the matrix.

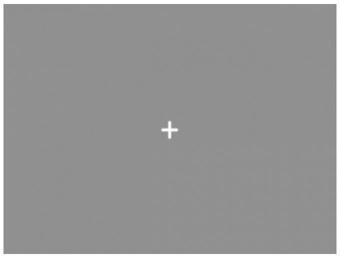
Sliding scale for actual trials:



You just saw a matrix of faces. Please indicate the answer that best fits the proportion of male and female faces in the matrix.

Appendix E - Summary Statistics Procedure

Fixation Point



2x2 Set Example

2x4 Set Example

3x4 Set Example

Masking Image