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Elevated rates of atypical handedness in paedophilia: Theory and implications

Rachel L. Fazio¹, Amy D. Lykins², and James M. Cantor^{1,3}

¹Law and Mental Health Program, Centre for Addiction and Mental Health (CAMH), Toronto, ON, Canada

²School of Behavioural, Cognitive and Social Sciences, University of New England, Armidale, NSW, Australia

³Department of Psychiatry, University of Toronto, Toronto, ON, Canada

Multiple factors determine handedness including genetics, prenatal stress and post-natal environmental conditions. Atypical handedness, whether manifest as increased sinistrality or decreased strength of lateral preference, has been noted in a wide variety of populations with neuropathology. Those with atypical sexual preferences, specifically paedophilia, also manifest reduced rates of right-handedness. This paper uses the largest sample of phallometrically assessed men to date to establish the pattern of atypical handedness in paedophilia. Specifically, whereas prior research has largely characterized participants dichotomously as right-handed or non-right-handed and/or used self-report of writing hand, this paper expands upon such reports by using the Edinburgh Handedness Inventory's laterality quotient. Participants' handedness and phallometrically assessed sexual preference were analyzed both as continuous and categorical variables, and the responses of those scoring in the range of ambiguous-handedness were evaluated to ascertain whether they were ambiguously handed or more accurately described as mixed-handed. Results indicated those producing scores in the range of ambiguous-handedness demonstrated response patterns consistent with ambiguous-handedness, rather than mixed-handedness. Paedophiles demonstrated high rates of non-right-handedness primarily manifested as sinistrality, whereas those who had a sexual preference for pubescent children evidenced increased ambiguous-handedness. Results support a view of ambiguous-handedness as less pathological than previously hypothesized, and of a neurodevelopmental origin of paraphilic sexual preferences.

Keywords: Handedness; Laterality; Paedophilia; Sex offenders; Phallometry.

Address correspondence to: Rachel Fazio, Centre for Addiction and Mental Health, 250 College St., Toronto, ON M5T1R8, Canada. E-mail: rlfazio@gmail.com

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Whereas the great majority of the population considers themselves either left-handed or right-handed, the picture becomes more complicated when hand skill and preference are assessed in detail. Portions of the population may actually be *ambidextrous*, *ambiguously handed* or *mixed-handed*. Ambidexterity is the presence of equivalent dexterity bimanually, regardless of whether the measure is of preference or of skill (Soper & Satz, 1984). For example, one may be able to throw equally well with both the left and right arm. Ambiguous-handedness, by contrast, involves a relative lack of preference for or skill with either hand (Soper & Satz, 1984). In the case of ambiguous-handedness, one may randomly use one extremity or the other for a task and may not be particularly skillful using either. Mixed-handedness is when an individual does have preference or skill for one or the other hand on tasks, but this preference varies across tasks (such as consistently opening the lid of a jar with the right hand but throwing with the left hand; Annett, 1970). The literature is incomplete concerning non-right-handedness and paedophilia (erotic interest in prepubescent children; von Krafft-Ebing, 1965). Although self-report data have been described, no study has yet examined the rates of *measured* left-handedness or ambiguous-handedness in individuals with phallometrically assessed deviant sexual preference.

Lateral preference other than left or right is considered atypical. The Satz model of handedness (Satz, 1972; Soper & Satz, 1984) was the first to attempt to explain the presumably pathological origins of ambiguous-handedness. The model proposed that in normal populations, the prevalence of left-handedness was approximately 8% and the prevalence of ambiguous-handedness was 0%. In populations with brain damage of non-specific but early origin, however, most would shift from their natural right-handedness to pathological left-handedness. If the brain damage were severe and bilateral, the most likely outcome would be ambiguous-handedness due to the brain being unable to lateralize successfully (Soper & Satz, 1984). Subsequent research has partially supported Satz's model. Nearly 12% of people residing in the USA consider themselves left-handed, as do over 12% of those in Canada (Perelle & Ehrman, 1994). Fewer than 4% consider themselves ambidextrous, which is higher than the nearly 0% prevalence of ambiguous-handedness theorized in a "normal" population, but still less than the proportion of the population that considers themselves left-handed.

The brain damage Satz proposed to explain atypical laterality would have to occur very early in life, as there is some evidence that hand preference can be ascertained among fetuses at 10 weeks' gestation (Hepper, McCartney, & Shannon, 1998). Research concerning handedness in infants and toddlers is beginning to support the early development of handedness as well. While infants, only 39% of children were lateralized right and 61% demonstrated no lateral preference; by toddlerhood, 97% demonstrated a distinct lateral preference (Nelson, Campbell, & Michel, 2013).

A variety of prenatal and perinatal factors have been associated with atypical patterns of handedness. Some of these are the prototypical injuries evoked when thinking of prenatal and perinatal “brain damage,” such as overt gestation and birth problems (e.g., hypoxia), whereas some are more subtle developmental insults. These include exposure to teratogens such as alcohol (Domellöf, Rönnqvist, Titran, Esseily, & Fagard, 2009), ultrasound (Salvesen, 2011), maternal stressors including infertility treatment or unplanned pregnancy (Zhu et al., 2009), maternal anxiety (Glover, O’Connor, Heron, Golding, & the ALSPAC Study Team, 2004) and maternal depressive symptoms (Rodriguez & Walderström, 2008). Low birthweight and premature birth are also known to affect lateralization; meta-analytic findings have indicated there is an approximate doubling of non-right-handedness [odds ratio (OR) = 2.12] in children born prematurely as compared with those who reached full-term gestation (Domellöf, Johansson, & Rönnqvist, 2011). In other words, those who are born from full-term pregnancies manifest about a 12% rate of non-right-handedness as compared with 22% of those born preterm.

Similarly, a wide range of populations manifesting neuropathology also have atypical patterns of handedness. One of the best-studied relationships between handedness and neuropathology is that of left-handedness and epilepsy (Isaacs, Barr, Nelson, & Devinsky, 2006). Increased rates of atypical handedness have also been demonstrated in those with autism spectrum disorders (Satz, Soper, Orsini, Henry, & Zvi, 1985), intellectual disability (Grouios, Sakadami, Poderi, & Alevriadou, 1999) and schizophrenia (Dragovic & Hammond, 2005).

Research has linked paedophilia and sexual offending against children with elevated rates of non-right-handedness. The first of these studies utilized a sample of over 8,000 archival records from the Kinsey Institute (Bogaert, 2001). In that report, handedness was self-reported as right, left or ambidextrous. Controls—individuals who had no history of criminality or sexual offending—were 11.4% non-right-handed, whereas those who were criminals, whether sexual or non-sexual offenders, had a 14.2% rate of non-right-handedness. Those who had committed a sexual offence against an unrelated child were 16.3% non-right-handed. There was a significant difference between offenders against children and controls in their rates of right-handedness, and analyses revealed that this was due to a larger percentage of offenders against children being ambidextrous, rather than left-handed. (See Table 1 for a further breakdown of the rates of handedness in that sample.) Overall, there was an approximately 30% increase in non-right-handedness in offenders against children as compared with controls.

Similar results were found by Cantor et al. (2004). They utilized a sample of 473 males meeting criteria for paedophilia through a review of the patient’s clinical records and volumetric phallometry. This study used a more sophisticated handedness measure than did Bogaert (2001) in that Cantor used a 9-item modified Edinburgh Handedness Inventory (EHI) to calculate a laterality

quotient (LQ; Oldfield, 1971). The LQ negatively correlated with phallometric response to erotic stimuli depicting prepubescent children, covarying out the effects of age and IQ. It also correlated with the participants' number of victims of childhood sexual abuse. These findings were partially replicated by the same research group with another sample of 404 adult men undergoing phallometric testing to ascertain their sexual preferences (Cantor et al., 2005). In this study, LQ again negatively correlated with phallometric response to erotic stimuli depicting children, but did not correlate with number of prepubescent victims. The prior and the current samples from this lab were then combined, and aggregate analyses were run. For these analyses, patients were classified as right-handed if they wrote with their right hand, and non-right-handed if any other response was recorded. The exact figures were not given, but non-right-handedness was approximately three times greater in paedophiles than in *teleiophiles* (individuals having their primary erotic interest in adults; Blanchard et al., 2000). These results were deemed to be specific to those with paedophilic sexual interest—individuals who sexually offended against adult women had typical rates of right-handedness.

Handedness was re-examined by the same lab to rule out whether the previous associations between paedophilia and handedness were an artefact of referral source (Blanchard et al., 2007). This sample consisted of 832 men who were classified as right-handed or non-right-handed. Paedophiles had odds more than twice that of those attracted to adults for non-right-handedness (see Table 1).

This pattern of atypical handedness in paedophiles suggested that population might provide insight regarding non-right-handedness as a marker of developmental hardship given that they have similar rates of non-right-handedness to

TABLE 1
Handedness across groups

Group	% Left-handed	% Ambiguously handed	% Right-handed
	% Non-right-handed		
Bogaert (2001)			
Controls	7.9	3.5	88.5
Criminals (sex/non-sex)	9.5	4.7	85.8
Non-sex offenders		15.4	84.6
Sex offenders		13.5	86.5
Offenders against children	9.7	6.6	84.3
Blanchard et al. (2007)			
Paedophiles		25.5	74.5
Hebephiles		16.5	83.5
Teleiophiles		11.9	88.1

Paedophilia refers to erotic interest in prepubescent children, *hebephilia* refers to erotic interest in pubescent children and *teleiophilia* refers to erotic interest in adults.

several other populations with established developmental pathology, such as foetal alcohol syndrome, schizophrenia and epilepsy (Domellöf et al., 2011; Dragovic & Hammond, 2005; Isaacs et al., 2006). The literature on handedness hypothesizes that ambiguous-handedness is more pathological than is manifest left-handedness, as it represents a failure of the brain to lateralize successfully. That hypothesis, however, is not well-borne-out amongst small samples, as those who are mildly affected by certain forms of neuropathology often have similar rates of ambiguous-handedness as do those who are severely affected (Satz et al., 1985).

As such, we hypothesized that manifest left-handedness may represent a more pathological condition if early factors influencing lateralization disrupted development so severely as to cause a complete reversal of one's natural handedness, versus a failure to strongly lateralize only some functions. Paedophilia shows a greater departure from typical than does *hebephilia* (the erotic interest in pubescent children; Glueck, 1955) or *teleiophilia* in several other domains, including general intelligence (Cantor, Blanchard, Robichaud, & Christensen, 2005), grade failure and placement in special education classes (Cantor et al., 2006) and differences in self-reported height (Cantor et al., 2007). Therefore, we expected paedophiles would demonstrate higher rates of left-handedness than either of those groups, rather than elevated rates of ambiguous-handedness.

MATERIALS AND METHODS

Participants

All study participants were recruited from the Kurt Freund Laboratory of the Centre for Addiction and Mental Health (Toronto, Ontario, Canada), which provides evaluation services to male patients referred as a result of illegal or clinically significant sexual behaviours or interests.

As with the prior studies from this facility, analyses were conducted on the cumulative data set established from clients who consented to the use of the clinical data for research purposes. Available for analysis were data from 1857 individuals assessed between the years 2000 and 2011. Thus, approximately half of the present data set represents new cases, whereas the others were included in prior studies. [Cantor et al. (2004) reported on assessments conducted in 2000–2002; Cantor et al. (2005), in 2000–2003; and Blanchard et al. (2007), in 2000–2006.] The research protocol was approved by the Research Ethics Board of the Centre for Addiction and Mental Health.

The primary source of referrals to the facility was parole and probation officers (42.6%), with physicians (12.8%) and lawyers (16.6%) providing others. The standard clinical assessment consisted of a psychophysiological (phallogometric) examination of the patients' erotic preferences (described further, below),

a semi-structured interview of their sexual history and interests, a review of supplementary psychiatric and legal documents supplied by the referral source, a brief questionnaire and a modified EHI.

The majority of the participants were Caucasian (75.7%), and the next largest group was Black (7.3%). There were also a substantial proportion of East Indian/Pakistani men (4.5%). The great majority of the sample (99.7%) underwent assessment between 2000 and 2011. The sample had a mean age of 38.8 years ($SD = 13.6$). The median education level was high school graduation.

Of the entire sample, 42.2% were known to have committed a sexual offence against one or more victims aged 10 and younger, 35.7% against one or more victims aged 11–14, 14.4% against one or more victims aged 15–16 and 28.6% against one or more victims aged 17 or above; 15.7% of the sample had no known victims of any sexual offences. These latter patients received assessments following charges of possession of child pornography or because of the patient's concern regarding his own sexual urges. The sum of these percentages exceeded 100% due to some patients having victims in more than one category. In this sample, no distinction was made between incest and non-incest offences.

MEASURES

Phallometric measurement of erotic gender and age preference

Participants' erotic interest in children versus adults was operationalized as their penile responsiveness to standardized stimuli depicting a variety of activities and persons of potential erotic interest. Phallometric assessment reliably distinguishes paedophilic from non-paedophilic men (Blanchard, Klassen, Dickey, Kuban, & Blak, 2001) and is the single most accurate predictor of recidivism among sexual offenders against children (Hanson & Bussière, 1998). The Kurt Freund Laboratory is equipped to conduct volumetric phallometry—the measurement of change in penile blood volume, which more accurately reflects responsiveness than does change in penile circumference (Kuban, Barbaree, & Blanchard, 1999).

A photograph and schematic drawing of the volumetric apparatus are given in Freund, Sedlacek, and Knob (1965). The major components include a glass cylinder that fits over the penis and an inflatable cuff that surrounds the base of the penis and isolates the air inside the cylinder from the outside atmosphere. A rubber tube leads from the cylinder to a pressure transducer, which converts changes in air pressure to changes in voltage output. Thus, any changes in penile volume during the presentation of stimuli compress the air in the cylinder, changing the signal from the transducer. The system reliably detects changes in penile blood volume <1 cc. Penile blood volume change is sampled four times per second and recorded as a curve of blood volume over time. A full erection, for most examinees, typically corresponds to an increase in volume of 20–25 cc.

The stimuli presented to examinees were audiotaped narratives played over headphones and accompanied by slides of full-body, nude photographs of persons of the corresponding age and sex. There were seven categories of narratives. These described sexual interactions with female prepubescent children, female pubescent children, female adults, male prepubescent children, male pubescent children, male adults or erotically neutral (i.e., non-sexual) activities. Neutral narratives were accompanied by slides of landscapes. The test stimuli were presented as discrete trials, 54 seconds in duration each, plus intertrial intervals as long as necessary for penile blood volume to return to baseline.

The full test consisted of four blocks of seven trials, each block including one trial of each stimulus type, in fixed pseudorandom order, yielding 28 trials. Each participant's 28 trials were converted to standard deviation units, relative to his own penile responses over the full set of trials (i.e., converted to ipsative z scores). These standardized scores were expressed as seven scores (one for each of the seven categories of stimulus) by averaging the four scores within each stimulus category. Finally, to produce a single score summarizing each patient's relative erotic interest in children, a *Phallometric Pedophilia Index* (PPI) was calculated as the arithmetic sum of the patient's responses to stimuli depicting children minus the arithmetic sum of his responses to stimuli depicting adults: $(\text{response}_{\text{prepubescent females}} + \text{response}_{\text{pubescent females}} + \text{response}_{\text{prepubescent males}} + \text{response}_{\text{pubescent males}}) - (\text{response}_{\text{adult females}} + \text{response}_{\text{adult males}})$. Thus, greater PPI values represented greater erotic interest in children.

Sexual offence history

Information from documents that accompanied the patient's referral, such as reports from police, probation or parole officers, was reviewed. Some patients themselves reported additional information regarding offences that were not included in their files and for which they had not been charged. A standardized form was used by the phallometric laboratory staff to record each patient's history of sexual offences. The coding of this information included each patient's numbers of victims aged 10 or younger, victims aged 11–14, victims aged 15–16 and victims aged 17 or above.

Measurement of handedness

Participants were administered a modified version of the EHI. The EHI was administered by the examiner asking the participant which hand he preferred for each of the ten activities; the participant was also asked to pantomime the last three activities (broom, match and box) to disambiguate responses. The evaluator marked either the "right" or "left" column (in a binary fashion, as opposed to the originally proposed system of "+" or "++" to indicate strength of preference) to

correspond with the participant's preference, or both columns if he expressed indifference.

Prior factor analyses of the EHI have revealed that items 8 and 10 (broom and box lid) have the poorest loadings on the handedness factor (McFarland & Anderson, 1980; Williams, 1986). These same items have poor reliability when compared with the other items of the inventory (McFarland & Anderson, 1980; Ransil & Schachter, 1994). An exploratory factor analysis of these data indicated the broom and box lid items demonstrated the poorest factor loadings; removing them significantly improved the proportion of the variance explained. Therefore, these two items were left out of the calculation of LQ for the participants. Laterality quotient was otherwise calculated as per Oldfield (1971, i.e., $[(R - L)/(R + L)]$ with R representing the number of right responses, L representing the number of left responses, and "either" answers being added to both R and L values).

Little has been published regarding LQ cut-off scores for ambiguous-handedness. Schachter (2000) proposed an LQ of <0 be considered left-handed, an LQ of 0 through 70 be considered weakly right-handed and an LQ of 71 through 100 be considered strongly right-handed. There is no theoretical reason, however, to consider weak left-handedness to be less important than weak right-handedness. As such, for this study, those with an LQ of >70 were considered right-handed, <-70 left-handed and those in between were deemed ambiguously handed.

Group assignment

Patients were first classified by both gender and age preference (i.e., heterosexual paedophile, homosexual paedophile, etc.), resulting in six total preference categories based only on their phallometric response. After analyses to determine if patient's gender preferences were in any way related to their handedness, patients were divided into three discrete groups for data analysis: paedophiles, hebephiles and teleiophiles. This categorization was done as per the procedures described in Blanchard et al. (2007). Essentially, the data were collapsed to disregard the patients' gender preference and reflect only their age preference. Thus, their responses to male and female prepubescent children were combined, as were their responses to male and female pubescent children, and male and female adults. Those who admitted to deviant sexual preference (i.e., attraction to children) were also added to the appropriate group, regardless of phallometric results. The PPI was also calculated for all patients. While theoretically values for this index could have nearly any range due to it being calculated from the participants' ipsative z scores, in this sample, values for this index ranged from about -5 to $+5$, with values in the positive direction indicating greater attraction to children.

RESULTS

LQ and handedness

The mean LQ for all participants was 71.1, whereas both the median and the mode were 100 ($SD = 59.4$). Using the aforementioned criteria to categorize participants' handedness, 80.9% were right-handed, 8.9% were left-handed and 10.2% were ambiguously handed. Due to prior research showing some relationship between sexual orientation and handedness, analyses were first conducted to determine if the relationship was present in this data. Of the total 1,857 men who participated in the research, 1576 could be classified into one of the six gender-by-age categories based on phallometric response alone. Cross-tabulation of gender/age category with handedness revealed differences in handedness between the groups, $\chi^2(10, n = 1,576) = 24.5, p = .006$. Visual inspection of the data revealed a tendency for those in similar age-preference classifications, as opposed to similar gender-preference classifications, to have similar rates of handedness. For example, 7.2% of those with heterosexual teleiophilic preference were left-handed, as were 7.3% of those with homosexual teleiophilic preference. Similarly, 78.9% of those with heterosexual hebephilic sexual preference were right-handed, as were 76.2% of those with homosexual hebephilic preference. The groups were then collapsed by gender preference (homosexual and heterosexual); and chi-square assessing handedness across the groups was again performed. This test revealed no significant difference in the distribution of handedness between those of homosexual and heterosexual gender preference, $\chi^2(2, n = 1576) = 3.181, p = .204$.

Participants were then split into groups based on their phallometric results with gender preference collapsed and admissions to deviant sexual preference added, permitting more participants to be classified by age preference. This allowed 1,712 men to be classified as paedophilic, hebephilic or teleiophilic. Both the participants' LQs and the rates of right-, left- and ambiguous-handedness varied across groups. LQ increased across the groups, from paedophilic to hebephilic to teleiophilic. The pattern of handedness demonstrated

TABLE 2
Handedness across groups

Group	n	% Left-handed (166)	% Ambiguously handed (189)	% Right-handed (1502)
Paedophilic LQ = 59.8 (69.9)	219	14.6	11.0	74.4
Hebephilic LQ = 69.4 (60.5)	619	9.0	12.4	78.5
Teleiophilic LQ = 74.9 (55.4)	874	7.4	8.8	83.8

Standard deviation for LQ is presented in parenthesis. The raw number of those classified by handedness and those classified by sexual preference differs because not all phallometric profiles were able to be classified discretely.

that those classified as paedophiles had the highest rate of left-handedness, while those classified as hebephilic had the highest rate of ambiguous-handedness, and finally, those classified as teleiophiles had the highest rates of right-handedness (see Table 2).

Correlation between LQ and PPI was examined. Due to the extreme non-normality of LQ score, the correlation was calculated using Spearman's rho; given the already established directionality of the relationship, this was run as a one-tailed test. LQ correlated with participants' paedophilia index scores, $r(n = 1,588) = -.043, p = .042$.

Due to the seeming difference in handedness across groups and established correlation between paedophilia index score and LQ, an ordinal chi-square test was performed to ascertain whether the apparent difference was statistically significant. Results indicated the distribution of handedness did significantly differ among groups, $\chi^2(1, n = 1,712) = 13.62, p < .001$.

Jonckheere's trend test (Jonckheere, 1954) was used to assess for differences in LQ amongst the age-preference groups. Jonckheere's trend test was selected for these analyses due to its increased statistical power when samples have a priori ordering, i.e., there is a suspected or known directional relationship. There was a statistically significant difference among the groups, standardized $S = 2.77, p = .006$. Similarly, when participants were grouped by handedness, the PPI was significantly different among the groups, standardized $S = -2.2, p = .028$. Whereas those who were left-handed had a paedophilia index of .12 ($SD = 1.79$), those who were ambiguously handed had a paedophilia index of .03 ($SD = 1.75$) and those who were right-handed had a paedophilia index of $-.15$ ($SD = 1.73$).

Education level demonstrated a significant difference between phallometrically assessed groups, but only a trend towards difference when grouped by handedness. Those who were left-handed had a mean of 11 years of education, with those who were ambiguously handed completing 11.8 years of education and those who manifested right-handedness completing 11.7 years (standardized $S = 1.67, p = .095$). A series of Mann-Whitney U tests were then performed to establish any significant differences between the groups. These revealed a difference between those who were left-handed and ambiguously handed, $U = 12611.5, z = -2.51, p = .012$, and between those who were right-handed and left-handed, $U = 103998.5, z = -2.69, p = .007$. There was no significant difference between those who were ambiguously handed and right-handed, $U = 135700.5, z = -.46, p = .649$. Alternately, whereas paedophiles completed 11 years of education, hebephiles completed 11.5 years and teleiophiles completed 11.9 years (standardized $S = 3.97, p < .001$). Mann-Whitney U tests were again run, indicating significant differences between all three groups (paedophilic/hebephilic, $U = 58899, z = -2.36, p = .018$; paedophilic/teleiophilic, $U = 77184, z = -4.1, p < .001$; and hebephilic/teleiophilic, $U = 246643, z = -2.21, p = .027$).

The foregoing invites the question of whether the participants were truly ambiguously handed (as would be denoted by a high number of "either"

responses) or whether it was a mix of “left” and “right” responses which pulled the LQ towards zero in the ambiguously handed group, which would make the more accurate label for this group “mixed-handed.” Only 9.4% of the sample had any “either” responses, although nearly half of those who did had more than one. Of note, all of those with more than one “either” response were in the ambiguously handed group. Of those who had been labelled ambiguously handed, 57.1% had at least one “either” response, compared with 6.6% of those who were left-handed and 3.7% of those who were right-handed. These differences were significant across groups, Kruskal–Wallis test, $\chi^2(2, n = 1,857) = 594.6, p < .001$. To ascertain where the differences were amongst the groups, a series of Mann–Whitney U tests were then performed, with the ambiguously handed participants having more “either” answers than either those who were left- or right-handed, but with no difference between the left- and right-handed groups, $U = 7355.5, z = -10.3, p < .001$; $U = 64051, z = -24, p < .001$; and $U = 121053, z = -1.8, p = .07$, respectively.

Mixed-handedness also was investigated in those who were classified as either left- or right-handed. Those who were right-handed indicated they used their less-preferred hand for one task 9.1% of the time, whereas 27.1% of those classified as left-handed used their right hand for one task. No participant classified as either right- or left-handed used their other hand for more than one task, although two of the right-handed participants (0.1%) did indicate using their left hand for one task and either hand for one task.

DISCUSSION

In summary, paedophiles demonstrated high rates of non-right-handedness, primarily manifested as sinistrality, whereas those who had a sexual preference for pubescent children evidenced increased ambiguous-handedness. Analysis of LQ scores indicative of ambiguous-handedness demonstrated that this was the correct classification as opposed to mixed-handedness. Results support a view of ambiguous-handedness as less pathological than previously hypothesized, and of a developmental origin of paraphilic sexual preferences.

Rates of left-handedness in most neurologically typical populations are at or below about 11% (Perelle & Ehrman, 1994). Broadly defined ambidextrousness is especially rare, with rates generally below 2% (Perelle & Ehrman, 1994). The participants in this study were all clinically referred for some sort of sexual behaviour difficulties; in other words, even the teleiophiles were not entirely typical. Their lateral preference followed suit, with a rate of 8.8% ambiguous-handedness and 7.4% left-handedness. Those who could be identified as hebephilic demonstrated a very similar pattern, with 9% left-handedness but 12.4% ambiguous-handedness. Paedophiles, however, demonstrated an accentuation of atypical lateral preference, with an elevated rate of both left-handedness

(14.6%) and ambiguous-handedness (11%). Given the hypothesis that ambiguous-handedness is less indicative of neuropathology than left-handedness, the extant research suggesting both that those with ambiguous-handedness should be grouped with those who are right-handed (Vuoksima, Koskenvuo, Rose, & Kaprio, 2009) and that paedophiles have several other markers of pathology (Cantor et al., 2005, 2006, 2007), the hypothesis has been supported.

The other supportive evidence of this hypothesis is that those categorized as paedophiles completed fewer years of education than those with either hebephilic or teleiophilic sexual interests. This is in line with other research which ascertained that individuals with paedophilic sexual interests also have a lower IQ (Cantor et al., 2004, 2005), poorer performance on other cognitive tests (Cantor et al., 2004) and more grade failures or placement in special education classes (Cantor et al., 2006).

Interestingly, all of these factors point to a perturbation early in the individual's development, as does other research indicating paedophiles are more likely to have incurred head injuries prior to the age of 13 (Blanchard et al., 2002; Blanchard et al., 2003). Paedophiles also have lower self-reported height than do hebephiles or teleiophiles (Cantor et al., 2007), and height is a well-established marker of developmental health (Batty et al., 2009). Preliminary research has also begun to demonstrate paedophiles have more minor physical anomalies, which are benign abnormalities indicative of stressors during prenatal development, than do teleiophiles (Murray, Dyshniku, Fazio, & Cantor, 2013). These factors, combined with the research indicating a large contribution of prenatal and perinatal factors to the development of handedness, indicate that whatever chain of events results in a sexual preference for prepubescent children, it begins early in development and leaves a sequence of physical and neurological markers during its progression.

This study demonstrated a statistically significant increase in atypical handedness in paedophiles due to both the large sample size and the high rates of atypical laterality. As noted by Coren (1993), extremely large sample sizes are needed to detect shifts in the handedness distribution of a population, as even a 50% increase in atypical handedness will still only be detected approximately 70% of the time when the sample is 1,000 participants, given the low base rate of non-right-handedness in a typical population. As such, any future replication or expansion of this study will require similarly large samples.

This difficulty may be ameliorated somewhat, however, by the use of more sensitive measurements of laterality. For example, the calculation of a Laterality Score (LS; Schachter, 2000) rather than LQ may increase sensitivity by better accounting for degree of hand preference rather than the current binary classification. A new handedness measure, the Fazio Laterality Inventory (Fazio, Dunham, Griswold, & Denney, 2013), may also demonstrate increased sensitivity to atypical patterns of laterality in this or other neuropathological populations; initial results demonstrate some support for this hypothesis (Fazio

& Cantor, 2013). Another future direction for this line of research would be further validation of this population's increased rate of ambiguous-handedness through repeat assessment of hand preference. This assessment of stability of preference—or lack thereof—across time, but within tasks, is necessary to solidify the differentiation of mixed or ambiguous-hand preference (Bishop, 1990).

While significant relationships were established in this paper between handedness and paedophilia, it should be noted that handedness accounted for approximately 0.2% of the variance in paedophilia. This is not surprising though, given that the developmental origin of paedophilia is currently unknown, and that paedophilia had been linked with a number of developmental perturbations. Adding more of these variables to a predictive equation (i.e., handedness, education, IQ, height, etc.) would likely lead to a higher proportion of variance explained, but would still fail to elucidate the exact developmental trajectory necessary for the establishment of paedophilic sexual preference. Similarly, while the volumetric phallometric testing used in this sample is considered a gold standard of evaluation for the assessment of paedophilia, classification is not without some margin of error, perhaps also reducing the explainable variance. Given the burgeoning evidence demonstrating a link between paedophilia and other developmental deviations which begin in the prenatal and early post-natal period, however, the categorization of paedophilia as a developmental rather than learned sexual preference is inescapable.

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