Measures of Handedness

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Abstract

Previous handedness research focused on comparing left-handers (LH) and right-handers (RH). Recently, researchers have compared consistent-handed and inconsistent-handed people, as defined by the Edinburgh Handedness Inventory (EHI). Consistent-handers (CH) typically use their dominant hand for nearly all manual activities whereas inconsistent-handers (IH) do not necessarily have a dominant hand or have no preference in hand use across several daily, manual activities. Degree of handedness is consistently found as the more robust variable in handedness research. Additionally, relying solely on self-reports to identify and categorize handedness instead of longer assessments of handedness, may not able a researcher to capture the subtle individual differences between handedness groups. 164 undergraduate Montclair State University psychology students completed a packet containing three handedness questionnaires. Results indicated that CH, as defined by the EHI, that chose either “left-handed” or “right-handed” were categorized as such by the EHI, but IH, as defined by the EHI, were more inconsistent with their hand preference choices depending on the number of choices available. A higher percentage of LH, compared to RH, all of whom were categorized as inconsistent-handed by the EHI, chose “ambidextrous” when provided a third choice. Degree of handedness and longer assessments of handedness able a researcher to find subtle differences between handedness groups that would otherwise not be identified when using direction of handedness (left vs right). Additionally, going beyond the traditional dichotomy of LH and RH in handedness research will allow researchers to more accurately predict cognitive and behavioral differences between handedness groups.
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/ Measures of Handedness /

by

Kyle Dodd

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Measures of Handedness

Early research on handedness differences primarily focused on direction of handedness (left versus right) (e.g., Heller & Levy, 1981; Nicholls, Chapman, Loetscher, & Grimshaw, 2010; Van Strien & Van Beek, 2000; Wright, Hardie, & Wilson, 2009). Recent research, however, has concentrated on degree of handedness (strong/consistent versus mixed/inconsistent) as the more germane variable in handedness research (e.g., Hardie & Wright, 2014; Lyle, Hanaver-Torre, Hackländer, & Edlin, 2012; McDowell, Felton, Vazquez, & Chiarello, 2015). It is currently being debated as to which variable, direction or degree of handedness, should be the primary variable to consider when conducting handedness research (Kaploun & Abeare, 2010; Peters, 1998; Prichard, Propper, & Christman, 2013). Prichard et al. (2013) in a literature review of the handedness paradigm, determined that degree of handedness showed more clear differences between handedness groups than did direction of handedness. For example, free recall of words, recall of events from one’s own life, knowing versus remembering, judgments, word recognition, cognitive dissonance, placebo effects, and anchoring effects all show differences between the consistent-handers (CH) and inconsistent-handers (IH), whereby some of that information would be lost if retaining the directionally – based categorization of handedness groups. Using degree of handedness helps better understand these differences between handedness groups.

Various categorization systems have been used to define handedness groups in past research. Researchers assessing handedness have parsed samples dichotomously by direction into left-handers (LH) or right-handers (RH) (e.g., Heller & Levy, 1981; Nicholls et al., 2010; Van Strien & Van Beek, 2000; Wright et al., 2009). Others have
parsed samples by degree of handedness into CH or IH (e.g., Lyle, McCabe, & Roediger, 2008; Niebauer, 2004; Prichard et al., 2013; Propper & Christman, 2004; Propper, Christman, & Phaneuf, 2005; Propper, Lawton, Przyborski, & Christman, 2004).

According to Prichard et al. (2013), CH are those who use a dominant hand (left or right) for nearly all manual activities and IH do not necessarily have a dominant hand, rather, they prefer different hands for different tasks, have no hand preference for some tasks, or a combination, as measured by the Edinburgh Handedness Inventory (EHI). Furthermore, some studies have focused on using a combination of both direction and degree of handedness within their sample (Luders, Cherbuin, Thompson, Gutman, Anstey, Sachdev, & Toga, 2010; Kaploun & Abeare, 2010; Peters, 1998), parsing their sample into four groups: consistent left-handers (CLH), consistent right-handers (CRH), inconsistent left-handers (ILH), and inconsistent right-handers (IRH).

Peters (1998) explored individual differences in motor task performance, and how those differences relate to preferred and non-preferred hand performance for RH and LH. Additionally, he explored how these motor tasks relate to hand preference classifications that are created by questionnaire responses. CRH were defined as those who indicated they write and throw a ball with their right hand. CLH were defined as those who write and throw a ball with their left hand. ILH were defined as those who write with their left hand, but throw a ball with their right hand. All participants filled out a 25-item questionnaire twice to identify hand preferences before and after performing the motor tasks. Results indicated differences between items on the questionnaire for only the RH and only when using degree of handedness as the primary variable. The IRH showed differences between choices for “pick up a small object” and “pick up a book” as
compared to the CRH and only when a longer assessment of handedness was used. Results indicate that degree, and not direction of handedness, may be the more important variable in studies of individual differences in handedness effects.

Propper, Brunye, Hrank, and McGraw (2013) investigated the relationship between height and handedness. Height was self-reported and handedness was assessed using the EHI, which is a self-report measure of handedness where participants respond to 10 daily tasks (e.g., writing, throwing a ball, opening a jar lid) on a 5-point scale (always right, mostly right, either hand, mostly left, always left). Scores from the 10 items are totaled and create laterality quotients (LQ) that range from –100 (complete left-hand preference) to 0 (no preference) to +100 (complete right-hand preference) (Oldfield, 1971). Results indicated no significant relationship between direction of handedness (LH and RH) and height, but the relationship between degree of handedness and height was significant. Inconsistent-handers were taller than CRH and CLH. Kaploun and Abeare (2010) examined the relationship between handedness and language lateralization. The researchers used a 22-item EHI, the Montreal Neurological Institute Handedness Questionnaire (MNI), and a 36-item Waterloo Handedness Questionnaire to determine handedness. Z-scores were gathered for each of the separate measures and then averaged across to create one composite score of handedness for each individual. A semantic priming task was used to identify differences in language lateralization where participants were presented with semantically related, unrelated, or non-word pairs (a non-word always appeared as the target [for 115ms], after a masking pattern of XXXX’s, and appeared randomly in either the left or right visual field). A prime word appeared on the screen, for 100ms, before the masking pattern. Participants then
indicated if the target word that appeared on the screen was a word or non-word using the associated keyboard keys for “yes” or “no” responses. Additionally, and of particular interest to this study, they wanted to explore any differences between various classification models of handedness previously discussed: RH vs LH, CRH vs CLH vs IRH vs ILH, CH vs IH, and CLH vs CRH vs ILH. They expected to find more differences between the handedness groups that were not defined in traditional terms (RH vs LH) if degree of handedness was indeed the key variable in finding these differences. Results regarding the directionally-based categorization of handedness (LH vs RH) revealed no significant differences. Results regarding the use of degree of handedness indicated that CLH showed a left visual field advantage, ILH showed no visual field advantage, and CRH showed a right visual field advantage, meaning that differences were observed when degree of handedness was considered, but not when direction of handedness was considered. These results would have been missed if directionally-based categorizations were used. Results from both studies remain consistent with the findings by Peters (1998).

Given that degree of handedness may be the more important variable to use in handedness studies, it is important to ask participants questions that allow for determination of handedness degree. Some studies have asked participants directly “Are you left- or right-handed?” or “What is your handedness?” (Coren, 1993; Reik, Reib, & Frye, 1998) whereas others have asked participants to self-describe or self-label their handedness (Elalmis & Tan, 2005; Elias, Saucier, & Guylee, 2001; Lippa, 2003; Peters, 1980). Some studies categorized participants’ handedness solely based upon writing hand (Hoptman & Levy, 1988; Levy, Heller, Banich, & Burton, 1983; Luh, Redl, & Levy,
1994; Stirling, Lipsitz, Qureshi, Kelty-Stephen, Goldberger, & Costa, 2013). These three different methods do not allow for the determination of handedness degree. However, those that have used longer questionnaires, such as the EHI, are able to include degree of handedness (Barut, Ozer, Sevinc, Gumus, & Yunten, 2007; Cosenza & Mingoti, 1993; Gunstad, Spitznagel, Luyster, Cohen, & Paul, 2007; Milenković, Rock, Dragović, & Janca, 2008). Accounting for degree of handedness by including a range of choices ("always left" to "either hand" to "always right"; i.e., the EHI), instead of directly asking "What is your handedness?" or "Are you left- or right-handed?", thus dichotomizing handedness into left- versus right-handed, would be more beneficial to capture individual differences in handedness effects (Chapman & Chapman, 1987; Coren, 1993; Reik, et al., 1998). Furthermore, Chapman and Chapman (1987), Coren (1993), and Reik et al. (1998) all agree that asking the singular question ("What is your handedness?") to identify and categorize people on their handedness does not correlate well with actual hand performance or accurately predict their behavior.

Lippa (2003) examined sex differences in handedness and personality trait differences. 933 men and women were recruited on a volunteer basis from a festival in California. Handedness was assessed using self-report as participants had to answer the question "Are you left – or right–handed?" using a Likert scale ranging from 1 (completely LH) to 3 (use both hands equally) to 5 (completely RH). They also used this scale to answer two more follow-up questions: "Which hand do you usually write with?" and "Which hand do you normally use to throw a ball?" Handedness categories were based upon their answer to the first question, thus those answering with a 1, 2, or 3 were grouped as non – RH and the rest were grouped as RH. An important finding from
their study was when a dichotomous directional parsing of handedness categories was used: LH and RH for heterosexual and homosexual women, no differences were observed. However, when degree of handedness was utilized, a significant difference between the handedness groups was observed. CLH women were more likely to be homosexual compared to CRH women whom were more likely to be heterosexual. Results showed a clear difference in utilizing the dichotomous directional parsing of handedness as compared to degree of handedness as well as indicating a possible need to include longer assessments (i.e., the EHI) in handedness research.

Lack of between group differences as a function of handedness on cognitive and behavioral tasks exists when examining participants' handedness simply by asking participants to indicate their handedness. For example, Elias et al. (2001) examined differences in depression as a function of handedness, and gender, specifically looking at differences between left - handed and right - handed college students. 486 participants self - labeled as RH and 55 as LH after being asked to indicate their handedness on the screening questionnaire that also contained the Beck Depression Inventory, which was used to assess self - reported depression. No main effect was found for sex or handedness. Stirling et al. (2013) examined visuomotor performance in relation to age, gender, and handedness. Handedness was determined by self - reporting of dominant writing hand (86% RH). Participants performed the Trail Making Test then a tracing task (following a red line clockwise around a circle four times using a stylus on a tablet). The tracing task was completed 14 times, seven times with each hand. Handedness showed a main effect for only one of their five variables and no effect of dominant hand use across the trials was observed. Both findings from Elias et al. (2001) and Stirling et al. (2013)
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show that there are minimal effects of individual differences in handedness on behavioral or cognitive measures when handedness is dichotomously divided as a function of left-versus right-handedness.

When utilizing a longer assessment of handedness, such as the EHI, handedness differences are more likely to be observed (Cosenza & Mingoti, 1993; Milenković & Paunović, 2015; Niebauer, 2004; Propper et al., 2004). Milenković and Paunović (2015) investigated the relationship between handedness, noise sensitivity, anxiety, and depression. Handedness was determined using the EHI, noise sensitivity was measured using Weinstein’s Noise Sensitivity Scale, anxiety was measured using the Hamilton Anxiety Rating Scale (HAM – A), Serbian version, and depression was measured using the Hamilton Depression Rating Scale (HAM – D), Serbian version. Handedness was categorized into four groups: strongly LH (-100 to -71), weakly LH (-70 to 0), weakly RH (0 to +70), and strongly RH (+71 to +100). Results showed that IRH and ILH had three times higher odds of self-reporting depression compared to CRH, which is important because Elias et al. (2001) did not observe this when they compared LH to RH.

Niebauer (2004) tested whether IH engaged in self-reflection more than CH and whether CH engaged in more self-rumination than IH. The EHI was used to identify participants’ handedness and the Rumination – Reflection Questionnaire (RRQ) determined rumination and reflection scores. No significant statistical differences between LH and RH were observed when performing analyses with directionally-based categorizations, but statistical significance was observed within the sample when degree of handedness was used (CH vs IH) as the primary categorical variable. Results indicate
that degree, rather than direction, of handedness may be the more important variable in
examinations of individual differences in handedness effects on cognition.

Propper et al. (2004) investigated the relationship between sleep architecture and
handedness in a naturalistic setting. Handedness was assessed using the EHI. Propper et
al. (2004) reported that across many of the variables used in their sleep study, the
participants’ degree of handedness had higher correlations with the sleep measures used
over the course of the experiment. Only one variable using direction of handedness
showed a significant correlation whereas using degree of handedness showed significant
correlations on 66.7% of the variables.

Of particular importance to this experiment is the choice LH would make when
provided dichotomous versus trichotomous choices and how that maps onto EHI
categories. Understanding how they self-identify when provided with additional choices
will be paramount in understanding whether self-labelling or simply asking participants
their handedness should not be considered for future handedness research. Chapman and
Chapman (1987) used a modified questionnaire that took 13 items from other
questionnaires such as: the 20-item EHI, the 12-item Annett Hand Performance
Questionnaire (AHPQ), and the 14-item Crovitz and Zener Questionnaire. Items included
activities such as: drawing, writing, using a bottle opener, throwing, using a hammer, a
toothbrush, an eraser, a tennis racket, scissors, a certain hand to hold a match, stirring a
can of paint, and asking about which shoulder the participant rests a bat upon before
swinging. A trichotomous choice was available to the participants whereby they could
choose either left, right, or either hand as their response to each item. Each item was
scored as 1 for “right”, 2 for “either”, and 3 for “left”. They reported that they used scores
that range from 13 to 17 as their category for RH, a slightly broader range for LH (33 to 39) since LH tend to be less consistent in their handedness as compared to RH, and those scoring from 18 to 32 were categorized as ambilateral. Chapman and Chapman (1987) reported that of the participants in their study (responding with either strongly RH, moderately RH, strongly LH, or moderately LH) that self-reported as RH were mostly, but not always, RH according to the questionnaire (91.1% for males and 94.2% for females). Only a little more than half of those self-reporting as LH were categorized as LH by the questionnaire (60.3% for males and 57.3% for females). Directly asking participants about their handedness was consistent among the consistent-handed population, for both RH and LH (96.9% for males, 98.8% for females; 81.7% for males, 82.8% for females, respectively). It appears there would not be as much error in asking CH directly about their handedness compared to IH, but it is the IH that provide more inconsistent results when directly having to report their handedness. In Chapman and Chapman’s (1987) study, it appeared a greater proportion of LH self-categorized as LH, yet almost half of those were categorized differently by the questionnaire! A much smaller proportion of RH were not categorized as RH by the questionnaire. This shows how important it is to use longer handedness assessments as compared to directly asking participants about their handedness, as self-labelling may not be nearly as reliable, especially those self-labelling as LH. Those who self-label as LH may be inaccurately categorizing themselves as compared to a longer assessment (e.g., the EHI), meaning the information obtained when analyzing results about handedness groups from self-labelling would be misleading.
In the current study, I investigated whether participants' self-designations as left- or right-handers are consistent with longer questionnaire assessments of handedness (i.e., the EHI). Additionally, I investigated how self-assessment using dichotomous or trichotomous preference choices “maps onto” the EHI. Studies that use self-assessment (using either dichotomous or trichotomous categories) may not be using the handedness groups that best demonstrate differences between groups in brain organization, cognition, and behavior (Chapman & Chapman, 1987; Coren, 1993; Elalmis & Tan, 2005; Kaploun & Abeare, 2010; Lippa, 2003; Peters, 1998; Prichard et al., 2013; Reik, et al., 1998). Additionally, I hypothesize that this dichotomous parsing by direction will only be valid for the most consistent-handers, but will not be valid for inconsistent-handers and for most participants who consider themselves to be left-handers.

Method

Participants

A convenience sample of 164 undergraduate psychology students at Montclair State University participated for extra or required credit in their courses. Participants were recruited through SONA (Sona Systems, Ltd.), an online software system for advertising research studies and timeslots for participation, and maintaining the MSU’s human participant pool. Participants were 38 males, Age $M = 19.87, SD = 2.09$; and 126 females, Age $M = 19.77, SD = 3.23$, for a total of 170 participants. Six participants were excluded from analysis because of missing data points resulting from failing to answer questions. All had normal or corrected – to – normal hearing and vision.

Materials
Packets included instructions, three self-report handedness measures (dichotomous, trichotomous, and EHI), confidence ratings, and questions about age and gender.

The dichotomous handedness measure consisted of one question, “Please circle the one that best describes you”, to which participants responded by circling the choices “Left-handed” (L) or “Right-handed” (R), appearing immediately below the question. The order in which responses were presented was counterbalanced across packets so that each packet included one of two possible response orders (LR or RL).

The trichotomous handedness measure consisted of one question, “Please circle the one that best describes you.”, to which participants responded by circling their choice of, “Left-handed” or “Ambidextrous” or “Right-handed”, appearing immediately below the question. The order in which responses were presented was counterbalanced across packets, so that each packet included one of six response orders (LAR, LRA, ARL, ALR, RLA, RAL).

The EHI was used to identify participants’ handedness and subsequent handedness category, by direction and by degree of handedness. Ten items (writing, drawing, spoon, open jars, toothbrush, throwing, broom [upper hand], scissors, knife, striking a match) are included on this self-report questionnaire and responses choices for each behavior were: always left, mostly left, no preference, mostly right, and always right. “Always” presents a score of positive or negative 10, “mostly” presents a score of positive or negative 5, and no preference presents a score of 0. Scores on the EHI range from -100, consistently-left-handed, to +100, consistently-right-handed. The total score is the sum of all of the responses. Participants mark the box indicating their hand preference
and strength of preference for the corresponding item. The EHI also includes questions regarding familial handedness, but these were not analyzed (see Appendix E).

The confidence ratings consisted of the question, “How much do you agree that your choice of handedness preference describes you?” Response choices were presented in a Likert-type scale, ranging from 1 (not at all) to 5 (agree strongly), and participants circled their choice. The questions about age and gender asked participants to report their age and indicate their gender by circling “Male” or “Female”.

**Procedure**

The order of questions within the packet was an incomplete counterbalance, where only the dichotomous and trichotomous handedness questions were counterbalanced, and both appeared before the EHI and questions about age and gender. As such, each packet included one of two possible orders of materials, each of which appeared on a separate page: 1) Instructions, followed by dichotomous handedness question and confidence rating, followed by trichotomous handedness question and confidence rating, followed by the EHI, and then age and gender; or 2) instructions followed by trichotomous handedness and confidence rating, followed by dichotomous handedness and confidence rating, followed by EHI, and then age and gender.

Due to an experimenter error, 24 unique packets (2 dichotomous response orders x 6 trichotomous response orders x 2 order of dichotomous and trichotomous questions), were created and distributed using the Latin Square Method, but packets were distributed unequally (each packet should have been distributed 7 times). Of the packet orders that were not distributed 7 times, the handedness option pages and their order remained
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counterbalanced and distributed equally across all participants. Age and gender information were also collected from the participants.

The participants were provided with the questionnaires to fill out. Group size varied from 5 to 20 participants per session. Participants took no more than ten minutes to fill out the packet. The experimenter handed out the questionnaires, and gave the following verbal instructions: “Please keep the packets face down for the time being. I will let you know when it is time to begin. At that time, you may turn the packets over and fill out the provided questionnaires. Be sure to read each page carefully and follow the instructions indicated on every page. If you have any questions as you fill out the packet, feel free to ask. Once you are done, bring the packet up to me.” The packets instructed each participant to only move forward during the experiment, that is, they were not to go back and change any previous answer or look at any previous responses. The experimenter remained in the room during the session, answered any corresponding questions, and collected the finished packets. At the conclusion, participants were thanked and packets were collected.

Results

The primary focus of this paper was to examine how people self-identify their handedness when provided a dichotomous and trichotomous hand preference option and how that maps onto their EHI preferences. Of particular importance is whether dichotomous or trichotomous handedness questions are as valid as using the EHI to determine handedness degree and direction. Remaining consistent with previous literature, (Jasper, Fournier, & Christman, 2014; Prichard et al., 2013; Propper et al., 2004) an EHI cut-off value of 80 was used to determine consistent and inconsistent
handedness where participants who scored 85 or above (absolute value) were classified as 
CH ($n = 98$), and participants who scored 80 or below were classified as IH ($n = 66$). On 
the dichotomous handedness measure, 9.1% ($n = 9$) of CH self-identified as left-handed, 
but 91.9% ($n = 89$) CH self-identified as right-handed. 19.6% ($n = 13$) of IH self-
identified as left-handed, and 80.4% ($n = 53$) self-identified as right-handed. Although 
the dichotomous test revealed a slightly less extreme disparity between left- and right-
handed self-identification for IH compared to CH, the pattern was the same. Using a 
dichotomous measure results in an overwhelming majority of individuals who self-
identify as right-handed, and is not a measure capable of discerning CH from IH, as 
defined by the EHI. Table 1 shows participants who self-identified as right-handed had an 
absolute value EHI $M = 82.57$ ($SD = 19.11$), and those who self-identified as left-handed 
had an absolute value EHI $M = 63.41$ ($SD = 33.14$). Absolute value EHI scores submitted 
to a one-way between groups ANOVA revealed a significant difference in scores 
between self-identified left- and right-handers ($F(1,162) = 15.19, p < .001, \eta^2 = .086$) 
where right-handers scored higher on the EHI compared to left-handers.

On the trichotomous measure, 9.1% ($n = 9$) of CH identified as left-handed, 0% ($n 
= 0$) of CH identified as ambidextrous, and 91.9% ($n = 89$) identified as right-handed. 
However, 15.2% ($n = 10$) of IH self-identified as ambidextrous, 12.1% ($n = 8$) self-
identified as left-handed, and 72.7% ($n = 48$) self-identified as right-handed. This 
suggests that CH may be more adequately identified using a dichotomous or 
trichotomous response choice, but that IH have greater diversity of handedness and 
classification benefits from the additional choice. Table 1 also shows participants who 
self-identified as right-handed had an absolute value EHI $M = 84.23$ ($SD = 17.03$), those
who self-identified as ambidextrous had an absolute value EHI $M = 28.00$ ($SD = 22.14$),
those who self-identified as left-handed had an absolute value EHI $M = 76.47$ ($SD = 22.34$). Absolute value EHI scores submitted to a one-way ANOVA revealed a
significant difference between self-identified left-handers, ambidexters, and right-handers
($F(2,161) = 46.13, p < .001, \eta^2 = .364$). Post hoc Scheffe tests indicate that RH scored
higher than all other groups, but not significantly different from the LH, and ambidexters
scored significantly lower than both RH and LH.

In addition, chi-square analyses were performed to test whether a relationship
exists between hand preference choices, through a dichotomous or trichotomous choice,
and degree of handedness (see Table 2). Results of the chi-square test revealed
significance: $X^2 (1, N = 164) = 3.75, p = .05$ for degree of handedness on dichotomous
choice and on trichotomous choice ($X^2 (2, N = 164) = 16.72, p < .001$), meaning that what
people chose to categorize themselves as is related to their degree of handedness, such
that those that were categorized as CH by the EHI, consistently chose (100%!) to be
either left- or right-handed regardless of handedness option. Those categorized as IH by
the EHI, however, showed more variation in their selection. Ten participants categorized
as IH by the EHI that chose LH ($n = 5$) and RH ($n = 5$) when provided the dichotomous
handedness option then chose “ambidextrous” when provided this third handedness
choice. Importantly, it was a greater percentage of LH (38.5%) compared to RH (9.4%)
that switched when given the extra choice, meaning LH are more likely to switch than
RH, given a third handedness option. All of those that switched were categorized as IH.
Table 2 shows variation within handedness categories depending on handedness
preference choice option. CH remained consistent across all conditions whereas IH varied
considerably more (see Figure 1), emphasized by the result that only IH chose the
"ambidextrous" option when it was available. This shows how important categorizing the
CH vs IH is, as the IH are more likely to choose differently than CH when handedness
preference choices go beyond the mere dichotomy of "left-handed" and "right-handed"
(see Figure 2). A chi-square analysis was also performed on dichotomous and
trichotomous choice to test if the two different hand preference choice options are related
(see Table 43). Results indicated a significant relationship: $X^2 (2, N = 164) = 142.48, p <
.001$, where those who choose LH or RH with a dichotomous option are likely to remain
consistent with their choice even with the addition of a third option in the trichotomous
choice option.

A point-biserial correlation was conducted to determine the relationship between
the dichotomous and trichotomous handedness preference choices and EHI scores,
respectively. There was a statistically significant strong positive correlation between
dichotomous choice ($r = .919, n = 164, p < .001$) and EHI scores, as well as a strong
positive correlation between trichotomous choice ($r = .511, n = 164, p < .001$) and EHI
scores. As mentioned above, CH consistently self-identify as LH or RH, yet IH identify
as LH or RH the majority of the time when given a trichotomous choice even though they
are inconsistently-handed, as defined by the EHI. A subset of both the IRH and ILH
chose the "ambidextrous" option (9.4% and 38.5%, respectively). When provided a third
option, those defined as ILH by the EHI, compared to IRH, are more likely to choose
something other than left- or right-handed.
Discussion

After examining the results of how CH and IH, as defined by the EHI, self-identify when given a dichotomous or trichotomous handedness choice option, the CH remained consistent in self-identifying as CLH or CRH. All CH, as defined by the EHI, chose to be LH or RH, respectively, regardless of how many options they were given.

The IH, as defined by the EHI, showed greater inconsistency when self-identifying their handedness. When provided with a dichotomous choice, most IH, chose to identify as a RH (80.4%), but when given a trichotomous choice (right-handed, left-handed, or ambidextrous) more IH chose to identify as ambidextrous than LH (15.2% vs 12.1%, respectively). A smaller percentage of RH, as defined by the EHI, chose to identify as RH (72.7%) given a trichotomous choice as compared to being given the dichotomous choice (80.4%). These findings remain consistent with previous literature (Chapman & Chapman, 1987; Coren, 1993) in that asking participants directly about their handedness not only depends greatly on how the question is phrased, but also shows the greater inconsistency in the IH population, as defined by the EHI, (specifically those self-identifying as LH) to map onto a categorical representation of handedness created by an assessment like the EHI. The dichotomous hand preference option was not able to fully capture the diversity of the IH, whereas the trichotomous hand preference option was more sensitive in identifying those that choose the extra option. In order to categorize handedness more accurately, including more than two options works best.

Results also showed that RH, LH, and ambidexters, and CLH, CRH, ILH, and IRH (all groups defined by the EHI) all scored significantly differently on the EHI and all in the expected directions. Although differences can be found using direction of
handedness to parse handedness groups dichotomously, the ANOVA results in this study indicated that adding a third handedness group was observed as being significantly different than CH and IH. Using direction of handedness would not able a researcher to identify these additional groups of handedness and to identify any subtle differences between the groups. It is important to include more handedness categories than just "left-handed" and "right-handed" in order to capture or observe these handedness differences.

The sample size used for this study was relatively small and future research should focus on using a larger sample in order to better capture smaller differences between handedness groups, especially for behavioral measures, which were not used here. Most samples obtained for handedness research will contain approximately 90% RH as they are more prevalent in the general population as compared to LH (Hardyck & Petrinovich, 1977; Prichard et al., 2013), and as replicated here as well. Cavill and Bryden (2003) argue that it is equally important to consider that handedness questionnaires may tap into different neural networks as compared to performance-based measures of handedness. For example, using a handedness questionnaire may place high demand on a cognitive process, like memory, to remember which hand they use for a particular task or more basically, which hand is their left or right hand. This would be compared to a performance-based measure that is an immediate indicator of hand preference as the participant is observed and the overall action reflects using a motor process in substitution of a cognitive process. Another important consideration when asking participants directly about their handedness is that the researcher subsequently loses the ability to know exactly which action or actions the participant has in mind when responding to the question. This could be rectified in future research if a question about
HANDEDNESS MEASURES

what memory or action they thought of is included. Chapman and Chapman (1987) note
that the correlation between a questionnaire and a subsequent performance – based
measure is roughly .83. Using either method, questionnaire or performance, will provide
meaningful results to handedness research so long as the handedness categories are
properly taken into account.

In sum, much of the literature in the handedness paradigm remains inconsistent
about how to categorize or how to ask participants most effectively about their
handedness. The present study aimed to shed light on the inconsistency and suggest that
degree of handedness be the primary variable considered when researching handedness
and that categorizing participants correctly is paramount to finding the subtle differences
between each of the handedness groups. Utilizing a longer assessment, such as the EHI,
is more effective at categorizing participants’ handedness compared to simply asking
them to indicate it, as shown by this study in the percentage of LH, as defined by the
EHI, that chose “ambidextrous” when given the option. The diversity shown in this study
with the IH and the LH, as defined by the EHI, and in Chapman and Chapman’s (1987)
study is why it is imperative to categorize handedness properly using a longer assessment
of handedness. IH, as defined by the EHI, may not reliably self – label their handedness
and solely relying on self – labelling can lead to misclassifications of handedness groups.
As handedness research moves forward, researchers should consider utilizing longer
handedness assessments to accurately categorize participants as opposed to simply asking
participants, “What is your handedness?”
### Means and Standard Deviations of Absolute Value EHI Scores According to Responses on the Handedness Measures

<table>
<thead>
<tr>
<th></th>
<th>Dichotomous Choice Measure</th>
<th>Trichotomous Choice Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Value EHI Scores</td>
<td>63.41 (33.14)</td>
<td>82.57 (19.11)</td>
</tr>
</tbody>
</table>

Note. Standard deviations appear in parentheses below means. Each column indicates the means and standard deviations according to the choice participants made when they were given a dichotomous or trichotomous choice.
Table 2

Chi-Square Analysis of Handedness Degree (Defined by the EHI) and Responses to the Handedness Questionnaires

<table>
<thead>
<tr>
<th>Questionnaire Type</th>
<th>Degree of Handedness (as defined by the EHI)</th>
<th>Response Option</th>
<th>$X^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Left – Handed (LH)</td>
<td>Right – Handed (RH)</td>
<td>Ambidextrous (Ambi)</td>
</tr>
<tr>
<td>Dichotomous Choice Measure</td>
<td>Consistent - Handled (CH)</td>
<td>9</td>
<td>89</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Inconsistent -Handed (IH)</td>
<td>13</td>
<td>53</td>
<td>N/A</td>
</tr>
<tr>
<td>Trichotomous Choice Measure</td>
<td>Consistent - Handled (CH)</td>
<td>9</td>
<td>89</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Inconsistent -Handed (IH)</td>
<td>8</td>
<td>48</td>
<td>10</td>
</tr>
</tbody>
</table>

Note. Numbers in each column beneath response option indicate the number of participants that chose the option in the associated column. Each row indicates their degree of handedness. For example, the first row represents 9 participants that chose “left-handed” and were categorized as CH by the EHI and 89 participants that chose “right-handed” and were categorized as CH by the EHI on the dichotomous choice measure (see Table 4 for means and standard deviations).
Table 3

*Chi-Square Analysis Examining the Relationship Between the Dichotomous and Trichotomous Handedness Measures*

<table>
<thead>
<tr>
<th>Trichotomous Choice Options</th>
<th>Left-Handed (LH)</th>
<th>Right-Handed (RH)</th>
<th>Ambidextrous (Ambi)</th>
<th>(X^2)</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dichotomous Choice Options</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left-Handed (LH)</td>
<td>17</td>
<td>0</td>
<td>5</td>
<td>142.48</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Right-Handed (RH)</td>
<td>0</td>
<td>137</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Numbers indicate the number of responses for participants based upon each measure. There were 17 total participants that responded with “left-handed”, 137 that responded with “right-handed”, and those choices remained consistent across both measures. Five participants that chose “left-handed” or “right-handed” on the dichotomous measure, respectively, chose “ambidextrous” on the trichotomous measure.
Table 4

**Absolute Value EHI Score Means and Standard Deviations for Consistent-handers and Inconsistent-handers on Each Handedness Measure**

<table>
<thead>
<tr>
<th>Degree of Handedness (as defined by the EHI)</th>
<th>Dichotomous Choice Measure</th>
<th>Trichotomous Choice Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left – Handed (LH)</td>
<td>Right – Handed (RH)</td>
</tr>
<tr>
<td>Consistent - Handed (CH)</td>
<td>93.9 (6.01)</td>
<td>94.4 (5.96)</td>
</tr>
<tr>
<td></td>
<td>93.9 (6.01)</td>
<td>94.4 (5.96)</td>
</tr>
<tr>
<td>Inconsistent - Handed (IH)</td>
<td>42.3 (26.82)</td>
<td>62.6 (16.86)</td>
</tr>
<tr>
<td></td>
<td>56.8 (16.46)</td>
<td>65.3 (14.49)</td>
</tr>
<tr>
<td></td>
<td>28 (22.14)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note. Standard deviations appear in parentheses below means. Means reflect absolute value EHI scores based upon the number of responses from each of the measures indicated in Table 2.
Figure 1. The Effect of Dichotomous Hand Preference Choice on Degree of Handedness.

Mean absolute value EHI score for CH and IH participants, as defined by the EHI, who chose “left-handed” and “right-handed” on the dichotomous handedness measure. Means for IH showed more variability compared to CH regardless of direction. Note: Error bars were created using standard error.
Figure 2. The Effect of Trichotomous Hand Preference Choice on Degree of Handedness. Mean absolute value EHI score for CH and IH participants, as defined by the EHI, who self-identified as “left-handed”, “right-handed”, or “ambidextrous”. Only IH chose the “Ambidextrous” option when it was provided, further emphasizing that IH display the most variation compared to CH. It is vital to handedness research to go beyond asking participants about their handedness dichotomously, and instead must focus on adding at least a third option since IH are more likely than CH to identify as something other than left- or right-handed. Note: Error bars were created using standard error.
Appendix A

Questionnaire Page 1: Instructions

Please fill out this packet.
If you have any questions, please ask the experimenter.
Please follow these instructions.
Once you have completed a page, continue only to the next page.
Once a selection is made, do not change any answers or go back.

Turn the page when you are ready to begin.
Please circle the one that best describes you.

Left - Handed

Right – Handed

How much do you agree that your choice of handedness preference describes you? (Circle one)

1 (not at all)  2(somewhat disagree)  3 (neutral)

4(somewhat agree)  5(agree strongly)
Once you have completed a page, continue only to the next page. Once a selection is made, do not change any answers or go back.

Please turn the page.
Please circle the one that best describes you.

Left – Handed  Ambidextrous  Right – Handed

How much do you agree that your choice of handedness preference describes you? (Circle one)

1 (not at all)  2(somewhat disagree)  3 (neutral)  4(somewhat agree)  5(agree strongly)
Edinburgh Handedness Inventory

Please indicate your preference in the use of hands for each of the following activities/objects by placing a check in the appropriate column.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Always Left</th>
<th>Usually Left</th>
<th>No Preference</th>
<th>Usually Right</th>
<th>Always Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drawing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spoon</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Jars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toothbrush</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Throwing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broom (upper hand)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scissors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knife</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striking a match</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Is your mother left-handed? __________
Is your father left-handed? __________
How many brothers & sisters do you have? __________
Are any of your brothers and/or sisters left-handed? __________
Please answer the following:

What is your age? ________

Please circle your gender:

Male  Female
It is okay to use your data in future studies:

Please circle one

Yes

No
References


