

The handedness of Leonardo da Vinci: A tale of the complexities of lateralisation

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Abstract

The handedness of Leonardo da Vinci is controversial. Although there is little doubt that many of his well-attributed drawings were drawn with the left hand, the hatch marks of the shading going downwards from left to right, it is not clear that he was a natural left-hander, there being some suggestion that he may have become left-handed as the result of an injury to his right hand in early adulthood. Leonardo's lateralisation may be illuminated by an obscure passage in his notebooks in which he describes crouching down to look into a dark cave, putting his left hand on his knee, and shading his eyes with his right hand. We carried out a questionnaire survey, using 33 written and photographic items, to find whether this behaviour was typical of right handers or left handers. In fact the 'Leonardo task' showed almost no direct association with handedness, meaning that it contributes little to the immediate problem of elucidating Leonardo's handedness. However, the lateralisation of the task did relate to other aspects of behavioural laterality in surprisingly complex ways. This suggests that individual differences in handedness, and behavioural laterality in general, have a structural complexity which is not fully encompassed by simple measures of direction or degree of handedness.

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1. Introduction

Leonardo da Vinci is probably one of the most famous left-handers in the world. There seems little doubt that his well-attributed drawings were carried out with the left hand (Venturi, 1939), the shading or hatching typically sloping downwards from left to right, that is $\backslash\backslash\backslash$, rather than in the more typical direction seen in drawings carried out by right-handers using their right-hand, where the hatching slopes down from right to left, that is $////$.

There is though a real problem in attributing drawings since, as Kenneth Clark put it, "all Leonardo's drawings are done with the left hand and the diagonal shading invariably runs down from left to right. . . . Almost every drawing attributed to Leonardo that is shaded from right to left is either unlike him in other respects or is demonstrably a copy" (Clark, 1968, Vol. 1, p. xvii). The problem is that this is a self-fulfilling prophecy, particularly with regard to the possibility that

early in his life Leonardo may have been right handed. There does however seem little doubt, as Clark points out, that from 1473, in a famous dated drawing of the Arno, Leonardo was mostly using his left hand. However, that same drawing, on the verso, does include an inscription written with the right hand (or, to be more precise, written from left to right) (Venturi, 1956, p. 89). Venturi concludes that "in his earliest drawings [Leonardo] seems to have employed both the right and the left hand to some extent, but he soon uses the left exclusively" (Venturi, 1956, p. 90). Venturi does argue that Leonardo's left-handedness was "congenital," and that "after the earliest drawings, in which he occasionally used the right hand," he was left-handed. That however seems unlikely; congenital left-handers do not usually "occasionally use their right hand," particularly for tasks such as drawing (although they do use the right hand for writing).

It is at least possible that Leonardo started out right handed, and had to become left handed because of an accident, and that after the accident he tried, for a while, to use the deformed right hand, a hypothesis proposed by Capener (1952) who suggested that at the age of

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about 20, Leonardo had a serious injury to the right hand, which was accompanied by some deformity.

Leonardo is famous for writing most of his manuscript notes in mirror-writing. Pacioli described the writing thus:

Scivesi ancora allo rovescia e mancina che non si posson leggere se non con lo spectro ovvero guardando la carta del suo rovescio, contro alla luce... [He wrote in the reverse direction and left-handed, so that it could only be read when held to a mirror, or by looking at the paper from the reverse, against the light...] (Critchley, 1928, p. 13).

Vasari also commented on Leonardo's left-handedness and mirror writing, saying of Leonardo how, "he wrote notes in curious characters, using his left hand, and writing from right to left, so that it cannot be read without practice, and only at a mirror" (Vasari, 1927, Vol. 2, p. 163).

Nevertheless Leonardo's mirror writing is not at all straightforward in its interpretation. The Royal collection at Windsor has two maps of Val di Chiana, numbers RL12278 and RL 12682 (Clark, 1968), which are reproduced in Clayton (1996, pp. 97–99). One is clearly a draft, and the writing is in mirror script, whereas the other is the final version, and the writing is written in the conventional direction from left to right. The scripts in the two are extremely similar (see McManus (2002) for illustrations). Schott (1999) points out that we will probably never know whether the normal script was written with the right or the left hand, although it has been claimed on the basis of graphological analysis that Leonardo used his left hand for the normal writing, as well as the mirror script (Poséq, 1997, p. 43).

The present study began after one of us had noticed a relatively neglected passage in the notebooks in which Leonardo describes the use of his right and left hands. While he had been walking in bright sunlight, Leonardo describes how he wished to see into a small dark cave:

Bending my back into an arch I rested my left hand on my knee and held my right hand over my down-cast and contracted eyebrows: often bending first one way and then the other, to see whether I could discover anything inside... (Richter, 1970, Vol. II, p. 395, #1339).

The passage is intriguing, not least because it is clear the event was vividly remembered by Leonardo and because he particularly records the specific actions of the right and left hand. It also occurred to us that this event might have something to say about Leonardo's natural handedness, particularly as informal studies suggested this way of bending down might be typical of the way that a *right*-hander rather than a left-hander carried out such a task. We therefore decided to find out how modern right- and left-handers would actually perform the task.

We wished to carry out the study by means of a questionnaire, but it was not straightforward to ask about this complex scenario by means of the verbal items used on most laterality questionnaires. We therefore developed a laterality questionnaire in which subjects not only answered questions about their laterality but also, for more complicated items, indicated which of two photographs corresponded to their usual preference. In developing this questionnaire we also took the opportunity to find out about the lateralisation of a number of other tasks which are often omitted from standard laterality questionnaires, such as wearing a watch or using a computer mouse. In particular we asked questions about mobile phone usage, particularly because this has become very common in recent years, there is little published information on the task, and there is some suggestion in patients with brain tumours that the laterality of phone usage may relate to the laterality of the tumour (Hardell & Hansson Mild, 2001; Rothman, 2001).

2. Method

The questionnaire consisted of four sides of A4 paper, printed on a single A3 sheet which was folded down the middle to make an answer booklet.

2.1. Questionnaire

The questionnaire contained several different types of question in the following order:

1. *Verbal questions.* The questionnaire began with nine fairly standard items which one of us has used before in previous studies (Marchant-Haycox, McManus, & Wilson, 1991; McManus, Naylor, & Booker, 1990), along with two additional items which have also been found to be useful, the hand used for throwing a ball (McManus, Porac, Bryden, & Boucher, 1999; Peters & Servos, 1989) and the hand used to hold a glass of water (Porac, 1993; Porac, Izaak, & Rees, 1990). On these and other verbal questions a six-point scale was used, "Always use right," "Usually use right," "Slightly prefer right," "Slightly prefer left," "Usually use left," and "Always use left." The six-point scale has the advantage that subjects always express a preference, however minimal, for the right or left side.

2. *Photographic questions.* Fifteen pairs of photographic questions occupied the next two and a half pages of the questionnaire. In each pair of photographs the picture on the right-hand side was the mirror-image of the photograph on the left-hand side. The photographs were grabbed as frames from a video in which a model demonstrated each of the actions. The model wore neutral-coloured clothes with no indication of laterality (e.g., no breast-pocket or buttons on the shirt), and

posed against a neutral coloured wall. The model was right-handed and carried out the actions in what for him was his typical fashion. When the photographs were used in the questionnaire they were randomly allocated to right or left of the page, and the mirror-image picture placed on the other side. A brief verbal description of each task was also given to clarify the actions of the right and left hands or sides. Fig. 1 shows the model posing for what we call the ‘Leonardo task,’ the action which Leonardo described in his notebooks, and was described at the introduction to this paper. The rubric for this section of the test was, “Below are pictures of a range of tasks. Indicate the typical way in which you would carry out each one by ticking *one* of the six boxes for each task.” The six boxes were marked “Always do this,” “Usually do this,” “Slightly prefer this,” “Slightly prefer this,” “Usually do this,” and “Always do this.” As with the verbal questions, a six-point scale was used to ensure that subjects always expressed some minimal preference.

3. *Mobile phone usage.* Four photographs were shown in which the subject was (a) holding the phone to the left ear and writing with the right hand, (b) holding the phone to the right ear and writing with the left hand, (c) holding the phone to the right ear with the left hand (‘crossed’), while writing with the right hand, and (d) holding the phone to the left ear with the right hand (‘crossed’) while writing with the left hand. Since writing hand was already known about this item was scored according to the ear to which the phone was held (right or left) and whether or not the hand was crossed or uncrossed.

4. *Miscellaneous.* The final page of the questionnaire asked about footedness (“Which *foot* would you use to

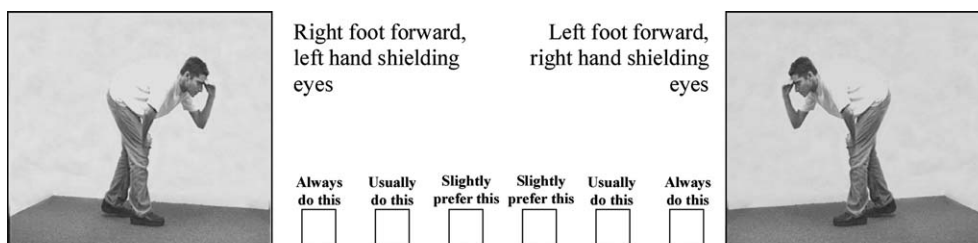
kick a ball at a goal?”), eyedness, (“With which *eye* would you look through a keyhole?”), using a computer mouse (“With which hand do you operate a computer mouse?”), and wearing a wrist-watch (“On which side do you wear your watch?”). There then followed the four diagrams from Levy and Reid (1976) which have been used to assess whether writing hand was normal or inverted (scored irrespective of hand used as a binary variable normal/inverted). The questionnaire finished with some brief questions on forced hand change, damage or injury to the hands, handedness of mother and father, age, and sex.

2.2. *Subjects*

The questionnaire was distributed to two groups of psychology students and two groups of medical students. In each case questionnaires were distributed at the beginning of a lecture and at least 90% of the students present at the lecture completed the questionnaire.

3. **Results**

The questionnaire was completed by 334 subjects, 102 males, 227 females, and 5 subjects who did not state their sex. The mean age was 20.03 (SD 1.85; range 18–31). Of the 334 subjects who described the hand they used for writing, all but five said they ‘always’ used a particular hand. Overall 27 (8.1%) of subjects wrote with the left hand and 307 (91.9%) wrote with the right hand. Some subjects were missing occasional values which were replaced by imputation from the most similar case.



	Right foot forward			Left foot forward			Total
	Left hand shielding eyes			Right hand shielding eyes			
	Always do this	Usually do this	Slightly prefer this	Slightly prefer this	Usually do this	Always do this	
Right-handers	15 (5%)	51 (18%)	60 (20%)	67 (22%)	79 (26%)	32 (10%)	289
Left-handers	3 (11%)	6 (22%)	5 (19%)	6 (22%)	7 (26%)	0 (0%)	27

Fig. 1. Responses of right- and left-handers on the Leonardo task shown in figure. The question and its associated pictures is shown at the top.

3.1. Handedness and the Leonardo task

Table 1 shows that both versions of the Leonardo task occur about equally often in right and left-handers (defined by writing hand), with no significant difference found ($\chi^2 = 4.911$, 5 df, $p = .427$). Combining the three 'left' responses and the three 'right' responses showed that overall 178 of the 307 right-handers (58.0%) reported placing the left foot forward while shielding the eyes with the right hand, whereas 13 of the 27 left-handers (48.0%) reported carrying out the task this way round. The small association with handedness is not significant ($\chi^2 = .990$, 1 df, $p = .322$).

These data clearly show that the handedness of Leonardo is unlikely to be predicted from a knowledge of how he bent down to look into a dark cave, since there is little correlation with handedness. That could be the end of the present story except that we began to wonder what, if it was not writing hand, might be associated with the way Leonardo bent down on that bright, sunny day. We therefore carried out an exploratory analysis to assess what variables amongst those we had measured were predictors of the direction of the Leonardo task.

3.2. Predictors of the Leonardo task

Overall we had information in our study on the lateralisation of 31 tasks, and in addition we knew about two factors related to lateralisation (an inverted writing hand position, and 'crossed' use of a mobile phone when writing), as well as two background measures, sex and age. We used a forward entry stepwise multiple logistic regression to ask which of these 35 background measures related to the direction of the Leonardo task. Because we were principally interested in *direction* of lateralisation we converted all of the measures to binary scales, according to whether responses were to right or left. The individual measures are shown in Table 1. The table also shows the proportion of subjects showing a 'left' response (which in some cases is somewhat arbitrary and is therefore defined). Stepwise regression can be overly liberal in its inclusion of measures, sometimes capitalising on chance, and we therefore set as an entry criterion that the log odds ratios should attain a minimum value of 1 (equivalent to an odds ratio of 2.72 \times), which is equivalent to a p value of about 0.001.

In the first stage of the analysis the **Leonardo task** is predicted significantly by only two variables, **Pick up object** (log odds ratio = 1.354, $p < .0005$) and **Shade eyes** (log odds ratio = 1.548, $p < .0005$). Of the 48 subjects who were left for **Pick up object** and **Shade eyes**, 37 (77%) were also left for the **Leonardo task**, whereas of the 158 subjects who were right for **Pick up object** and **Shade eyes**, only 31 (20%) were left for the **Leonardo task**. Those who were mixed for **Pick up object** and

Shade eyes were less consistently left or right for the **Leonardo task**—of 51 individuals who were left for **Pick up object** and right for **Shade eyes**, 29 (57%) were left for the Leonardo task, and of 77 individuals who were right for **Pick up object** and left for **Shade eyes**, 46 (60%) were left for the Leonardo task. Although many subjects are consistent for shading the eyes and for picking up an object (and most of these subjects are also consistent for the Leonardo task), there is a surprising number of subjects, $128/334 = 38.3\%$ who are inconsistent for shading the eyes and these subjects show no consistency for the Leonardo task.

Having found that only two of the tasks, **shade eyes** and **pick up object**, predicted the Leonardo task, it was then possible to ask what other lateralities predicted the laterality of these two tasks. We therefore regressed, in turn, **shade eyes** and **pick up object**, on all of the remaining variables (i.e., excluding each other and the Leonardo task). The result is shown diagrammatically in the right-hand side of Fig. 2. **Shade eyes** is predicted significantly both by **hand to forehead** and by **hand to mouth**, and **pick up object** is predicted significantly by **open can** and by **hand to mouth**.

The logic of the remaining analysis should by now be becoming clear. Each variable which is a predictor can itself be entered as a dependent variable, regressing it on all of the variables which have not yet been entered into the diagram. The process can then be repeated until every variable is either entered into the analysis or is not in any way a predictor of the **Leonardo task**. The analysis is comparable in many ways to that which occurs in path analysis, or causal path modelling, identifying both direct and indirect predictors of the final outcome measure of interest, the Leonardo task. Fig. 2 shows the final model. Of the 34 variables used to predict the Leonardo task, two are direct predictors, seven have no predictive value, and the remaining 25 are indirect predictors, 3 at one remove, 5 at two removes, 6 at three removes, 8 at four removes, and 3 at five removes. Of particular interest is that handedness (**Write with pen**) does relate to the Leonardo task, albeit indirectly, as also do other conventional measures of handedness (e.g., **thread needle**, **draw picture**). There is however no overall simple association of these measures with the Leonardo task because of confounding from other lateralities.

4. Discussion

This paper started out as a study to test a simple hypothesis—that Leonardo da Vinci may have been a right-hander by birth, and that his undoubted left-handedness for drawing may have been acquired later in life. The **Leonardo task**, as we have called it, of bending down on one leg and simultaneously shading the eyes, as

Table 1
The 33 measures of lateralisation

Variable name	Verbal or photographic	Description and definition of 'left'	%Left (or %inverted or %crossed)
Write with pen	Verbal	"To hold a pen while writing a letter"	8.1
Throw ball	Verbal	"To throw a ball at a target"	6.3
Draw picture	Verbal	"To hold a pencil while drawing a picture"	7.8
Dry dish	Verbal	"To hold a dish while drying it." Reverse scored so that 'left' indicates that the dish is dried with the left hand	16.2
Wind clock	Verbal	"To turn the winder on a clock"	6.3
Open jar	Verbal	"To hold a jar while unscrewing its lid." Reverse scored so that 'left' indicates that the jar is unscrewed with the left hand	22.2
Thread needle	Verbal	"To hold a thread while guiding it through the eye of a needle"	17.4
Knife with fork	Verbal	"To hold a knife when eating with a knife and fork"	19.8
Peel potato	Verbal	"To hold a potato while peeling it." Reverse scored so that 'left' indicates that the potato is peeled with the left hand	15.0
Sweep with broom	Verbal	"At the top of a broom when sweeping the floor"	25.1
Glass of water	Verbal	"To pick up a glass of water"	10.8
Kick ball	Verbal	"Which foot would you use to kick a ball at a goal?"	5.4
Eye dominance	Verbal	"With which eye would you look through a key-hole?"	26.9
Computer mouse	Verbal	"With which hand do you operate a computer mouse?"	2.1
Wrist watch	Verbal	"On which wrist do you wear your watch?"	83.8
Open can	Photographic	Opening a can of fizzy drink. Left indicates the ring-pull is operated with the left hand	13.5
Hand to mouth	Photographic	Putting a finger to the mouth as if to say "Shhhh. . . ." Left indicates left finger in front of mouth	31.4
Rest chin on hand	Photographic	Resting chin on palm of hand, with elbow placed on the table. Left indicates chin in left palm	37.4
Hand to forehead	Photographic	Slapping forehead with flat of palm in an expression of surprise or incredulity. Left indicates left palm used	29.9
Hold baby	Photographic	Cradling a baby with both arms underneath the baby. Left indicates baby's head is to the subject's left side	48.2
Count fingers	Photographic	Using the index finger of one hand to count the fingers on the other hand. Left indicates that the index finger of the left hand does the counting	29.9
Pick up object	Photographic	Bending forward to pick up an object with one hand, and with the contralateral foot forward. Left indicates object picked up with the left hand	29.6
Shade eyes	Photographic	Hand held to the forehead, with horizontal palm flat and facing downwards to shade eyes. Left indicates that the left hand is used	37.4
Leonardo task	Photographic	The Leonardo task, with one hand shading the eyes, and the contralateral hand on the ipsilateral knee, which with the ipsilateral foot is forward. Left indicates the eye is shaded with the left hand, that the right hand is on the right knee, and that the right foot is forward of the left foot.	42.8
Bag over shoulder	Photographic	Carrying a shoulder bag over one shoulder with the hand on the strap at shoulder level. Left indicates the bag is on the left and held by the left hand	24.9
Hand clasping	Photographic	Hand-clasping with the fingers of the two hands interlaced. Left indicates that the left thumb is on the top	55.4
Crossed legs	Photographic	Sitting cross legged on the ground. Left indicates that the left shin is forward of the right shin	38.3
Cross ankles	Photographic	Sitting in a chair with the legs fairly straight out in front and with the ankles crossed. Left indicates the left ankle is over the right ankle	29.6
Arm folding	Photographic	Arms folded with one hand tucked in under the contra-lateral upper arm, and the other arm resting on the contra-lateral upper arm. Left indicates the wrist which is on top	56.3
Fold hands	Photographic	Hands folded on the knee, with one hand covering the other. Left indicates the hand which is on top	29.0
Mobile phone	Photographic	Mobile phone held by the hand to the ipsilateral ear. Left indicates the ear to which the phone is held. (NB in this picture the other hand is <i>not</i> writing)	26.9
Crossed mobile phone	Photographic	Four pictures showing combinations of right and left writing hand and phone held to right or left ear. The variable is scored so that a 1 indicates the phone is 'crossed' (i.e., the holding hand is contralateral to the ear to which the phone is held), otherwise it is scored as a zero	10.8 (crossed)
Inverted writing	Diagrammatic	Four pictures from Levy and Reid (1976) showing the left hand in a normal or a hooked (inverted) writing position, and the right hand in a normal or a hooked writing position. Irrespective of the hand holding the pen, the item is scored as a 1 if the pen is held in a hooked position, and a zero otherwise	38.0 (inverted)

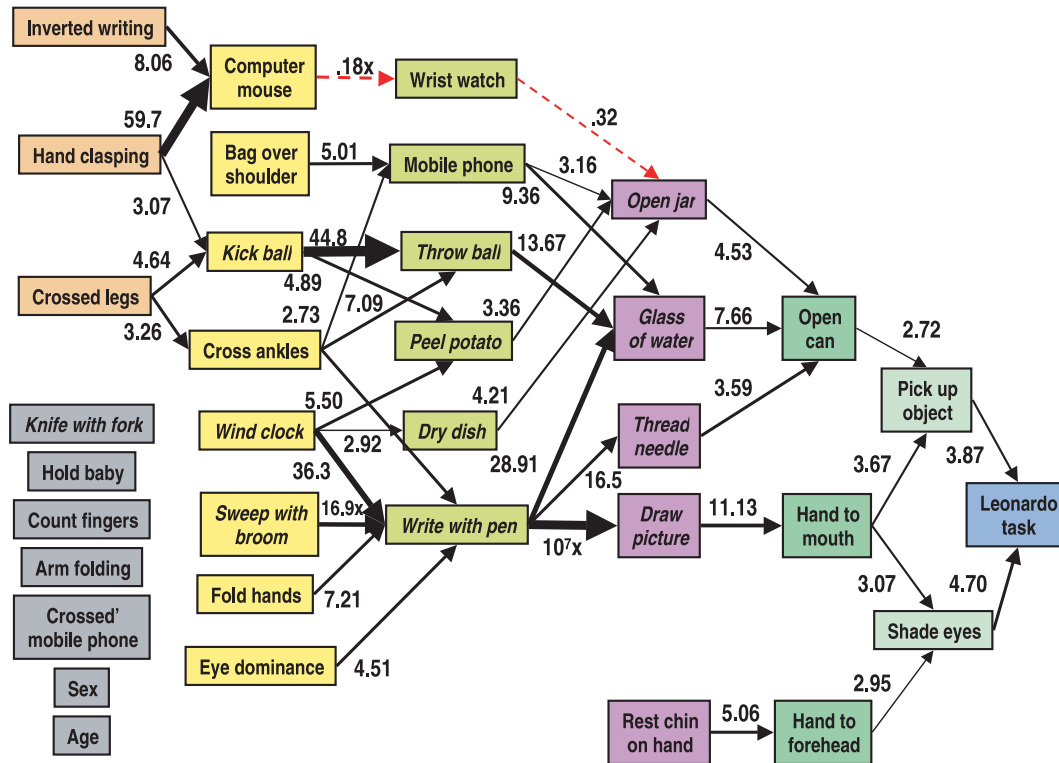


Fig. 2. The inter-relations of the Leonardo task and other lateralities.

Leonardo described when looking into a dark cave, seemed to provide a way of resolving the issue. A simple analysis in a large number of modern subjects showed, however, that the laterality of the Leonardo task was hardly related at all to handedness, conventionally defined as writing hand. A simple conclusion for this paper is therefore apparent B whether or not Leonardo was naturally right-handed or left-handed cannot be inferred from the action used by Leonardo when looking into the dark cave.

A useful spin-off from our interest in the Leonardo task had been the development of a novel form of questionnaire for assessing laterality in which the items were not only verbal but were also photographic. This had the advantage of being able to ask about items such as the Leonardo task which are simple to illustrate photographically but are complex and unwieldy to describe in purely verbal terms. In addition we also took the opportunity to ask about items of laterality which often are not measured in conventional questionnaires but about which there is interest and for which it is not clear whether they are related to handedness in the conventional sense of writing hand. In particular we included items such as leg crossing, and hand folding, as well as measures to do with wearing a wrist watch, using a mobile phone, and using a computer mouse. Rather like hand-clasping and arm-folding, which have long been established in the lat-

erality literature as pretty well independent of writing hand (McManus & Mascie-Taylor, 1979), so it was the case that these were relatively weakly associated with writing hand.

In order to make sense of the large number of measures of laterality we initially turned to factor analysis of the binary items, the six-point scales having been recoded into pure laterality measures or right/left. Conventional principal components analysis using SPSS yielded a scree-plot for which it was unclear as to the number of factors. That could, however, have been due to the known problems of factor analysing Pearsonian correlations derived from binary measures, due to what have been called ‘difficulty factors’—essentially extracting factors whose items are mostly similar in their means rather than their inter-correlations (Bernstein & Teng, 1989; Maxwell, 1977). To circumvent this problem we therefore used the program MFACT (Waller, 1995) to analyse the tetrachoric correlations, but this also gave an unclear scree-slope, and the patterns of loadings gave no clear indication of an obvious underlying factor structure or of its dimensionality, only suggesting that there were at least half a dozen or so factors (which is perhaps not unexpected given that we also had included writing and throwing hand, as well as footedness, leg-crossing (Reiss, 1994), hand-clasping and arm-folding (McManus & Mascie-Taylor, 1979), all of which at best show only weak inter-correlations).

In order to make sense of our data, particularly in the context of our original hypothesis concerning Leonardo, we therefore adopted a far more exploratory approach, akin in many ways to causal path modelling (Jöreskog & Sörbom, 1993; Maruyama, 1998), asking which measures are predictors of the Leonardo task, which measures are predictors of those predictors, and so on, the fairly complex result being shown in Fig. 2. Although not answering our original question about Leonardo (except in the sense that it is clear that the **Leonardo task** is not going to indicate Leonardo's innate handedness), it does illuminate some interesting aspects of laterality.

Perhaps most intriguing in Fig. 2 is the complexity of the inter-relations between measures of handedness which very often have been lumped together into a single 'laterality index.' Many lateralities, like the Leonardo task itself, are determined by two or more other lateralities, with even quite simple tasks such as **glass of water** being related separately to **write with pen**, **throw ball**, and **mobile phone** (and it should be emphasised that in Fig. 2 all of the predictors are statistically independent of one another).

Although Fig. 2 is couched in similar terms to a causal path diagram, there is no strict sense in which these paths can be truly interpreted as causal. That does not though mean that there are not true underlying causalities between these measures, although they are unclear at present. The complexities seen in Fig. 2 must however have developed in these individuals, and at some time a decision must have been taken, for instance, to wear a watch on the right rather than the left wrist, and that may have been related to other pre-existing asymmetries in that individual, as well as perhaps having an autonomous component of its own. Perhaps the major purpose of Fig. 2 is to indicate to laterality researchers how little we understand of the inter-relationships of this range of mundane and trivial yet very visibly obvious lateralised behaviours.

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