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What affects facing direction in human facial profile drawing? A meta-analytic inquiry†

Sümeyra Tosun[1], Jyotsna Vaid[2]
[1] Department of Psychology, Süleyman Şah University, Istanbul, Turkey;
[2] Department of Psychology, Texas A&M University, College Station, TX 77843-4235, USA;
e-mail: stosun@ssu.edu.tr, jvaid@tamu.edu
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Abstract. Two meta-analyses were conducted to examine two potential sources of spatial orientation biases in human profile drawings by brain-intact individuals. The first examined profile facing direction as function of hand used to draw. The second examined profile facing direction in relation to directional scanning biases related to reading/writing habits. Results of the first meta-analysis, based on 27 study samples with 4171 participants, showed that leftward facing of profiles (from the viewer's perspective) was significantly associated with using the right hand to draw. The reading/writing direction meta-analysis, based on 10 study samples with 1552 participants, suggested a modest relationship between leftward profile facing and primary use of a left-to-right reading/writing direction. These findings suggest that biomechanical and cultural factors jointly influence hand movement preferences and in turn the direction of facing of human profile drawings.

Keywords: object facing, drawing, directionality, scanning biases, manual preference, reading/writing habits, graphic production, facial profiles

1 Introduction

The ability to depict objects, animals, and other figures, evident from early artwork dating to prehistoric times (Humphrey, 1998), is a distinguishing skill of humans that is arguably as important in human history as hunting and gathering (Anderson, 2013). Studies of representational drawings of figures with an intrinsic or implied front and back typically reveal a preferred spatial orientation for object facing, as well as asymmetries in drawing starting location and in the direction of stroke movements (van Sommers, 1984). Differences in the size or direction of spatial biases in object facing have been related to whether the object to be drawn is animate or inanimate, static or capable of movement, or graspable, as well as to biomechanical factors such as tensor versus flexor movements in stroke production, and directional biases related to left-to-right versus right-to-left reading/writing experience (see Vaid, 2011).

The phenomenon of spatial biases in figure drawing, and of face representation in particular, has attracted the interest of researchers from a variety of subfields of psychology including clinical psychology (Hovsepian, Slaymaker, & Johnson, 1980), perception (Everdell, Marsh, Yurick, Munhall, & Pare, 2007; Nachshon, 1985; Yamamoto, Kowatari, Ueno, Yamane, & Kitazawa, 2005), motor cognition (Martin & Jones, 1999; van Sommers, 1984), developmental science (Picard, 2011; Scheirs, 1990), aesthetics (Benjafield & Segalowitz, 1993), social cognition (Brady, Campbell, & Flaherty, 2005; Suitner & Maass, 2011), and cognitive neuroscience (Alter, 1989; Chatterjee, 2002; Trojano & Conson, 2008; van Sommers, 1989). The present study sought to evaluate the determinants of directional biases in spatial orientation of drawings of the human face in profile view. In our study we used meta-analysis to assess the contributions of two different sources of directional bias in the orientation of facial profile drawings: hand-movement-related asymmetries arising from biomechanical

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factors associated with whether the right or left hand is used to draw and asymmetries arising from cultural factors (prolonged exposure to and predominant use of a left-to-right versus a right-to-left written language).

1.1 *Facial profile perception*

Faces convey socially highly relevant information such as an individual's age, sex, ethnicity, physical attractiveness, and emotional state (Brady et al., 2005; Bruce & Young, 2011). The ability to recognize whether a particular face is known to one or not known and whether it is conveying a particular emotional state is clearly important for human social interaction and may well determine how (or even whether) we will interact with that person.

Studies using gaze fixations have shown that viewers tend to look initially and more often to the left side of a face from the viewer's perspective (Everdell et al., 2007). Similarly, other research has shown greater visual exploration of core features of the left side of the face in right-eye-dominant individuals (Hernandez et al., 2009). Furthermore, it has been noted that faces presented in a left oblique orientation are recognized most easily (Yamamoto, Kowatari, Ueno, Yamane, & Kitazawa, 2005).

Using a face-matching paradigm in which participants had to decide if centrally presented frontal images of faces were the same as laterally presented profile views, Burton and Levy (1991) found (among right-handed fast responders only) that faces were matched faster in the left visual field when they faced rightward (from the viewer's perspective) but were matched faster in the right field when they were oriented leftward. The authors interpreted this finding in terms of a presumed right hemisphere superiority for medially directed implied movements (ie a preference for objects or scenes to be scanned in a rightward direction when the initial starting point is in the left visual field, and the converse for right field starting location). However, other studies suggest that left-to-right versus right-to-left scanning biases related to perceivers' preferred reading/writing direction could also underlie observed face matching biases (Megreya & Havard, 2011).

Aside from perceptual asymmetries, biases in the choice of orientation of paintings or portraits of faces have also been observed (see Powell & Schirillo, 2009, for a review). Specifically, in portraiture more of the left side of a poser's face tends to be depicted than the poser's right side. In a classic study McManus and Humphrey (1973) found that, of 1474 portraits from Western works of art from the 14th to the 20th century, about 60% showed posers whose left side of the face was more exposed. Similarly, Conesa, Brunold-Conesa, and Miron (1995) surveyed a large dataset of 4180 single-subject portraits including drawings, paintings, etchings, and photographs in Western art and found that the majority were left facing.

Experimental studies have confirmed the existence of side preferences in portraiture. For example, Bruno and Bertamini (2013) asked naive photographers to take pictures of themselves using a smart phone and subsequently evaluate those pictures. Corroborating the observational data obtained by previous researchers from works of art, Bruno and Bertamini found that nonartists also show a distinct side preference in their self-portraits. Similarly, Benjafield and Segalowitz (1993) obtained viewers' ratings of eight portraits drawn by Leonardo da Vinci. Participants were shown portraits that were either left looking or right looking from the viewer's perspective. It was found that left-looking portraits were rated as more 'potent' and 'active' than the same portraits looking to the right (see Lindell, 2013, for further discussion).

Thus, several studies concur in suggesting that the two sides of the face differ in their emotional expressiveness. What is not clear is why they may differ and whether the asymmetries observed reflect intrinsic structural properties of the two sides of the face or instead reflect attentional biases of the perceiver.

According to a commonly held view, the asymmetry in the display of emotional expressions arises from cerebral hemispheric differences in functional specialization, with the right hemisphere thought to be more specialized for visuospatial and emotional processing and controlling the lower half of the left side of the face (Powell & Schirillo, 2009). An alternative position proposes a social explanation for the different significance of the two sides of the face, arguing that the right side of the face conventionally represents the more public side and the left the more private side (Lindell, 2013). The latter account may be better able to explain the finding of changes over time in the portrayal of portraits of women in Western art as they assume more public roles (Grusser, Selke, & Zynda, 1988; Suitner & Maass, 2011).

Finally, Chatterjee (2002) introduced a new dimension to the study of facial profiles by proposing that agency plays a central role in influencing the directionality of the human face. He observed that right-handed people tend to locate agents (that is, those performing an action) in the left side of space from the viewer's perspective and that actions tend to be construed (at least by left-to-right readers) as proceeding from left to right (see also Suitner & Maass, 2011). Whatever the particular theoretical explanation offered, a variety of studies with brain-intact individuals concur in showing that people tend to recognize, produce, and prefer viewing facial profiles that look to the viewer's left.

Spatial representation in face drawings have also been used to assess various kinds of brain dysfunction (Pontius, 1997). Indeed, the drawing of common objects has been used for clinical purposes for a long time (eg Bartolomeo, 2007; Farias, Davis, & Harrington, 2006). A typical finding in this literature is illustrated by the study by Chokron, Colliot, and Bartolomeo (2004), who noted that drawings by individuals with right hemisphere damage tend to show left-sided neglect.

The Behavioral Inattention Test (BIT) has been designed to diagnose unilateral spatial neglect (Wilson, Cockburn, & Halligan, 1987). In one of the subtests of the BIT, patients are asked to draw a person. Omissions on the left side of the drawings are considered a sign of spatial neglect. Seki, Ishaiai, Seki, and Okada (2010) offered a new diagnostic measurement for BIT in terms of the percentage deviation of the eyes from the midline in the drawing of the face outline. Of three groups tested on this task—right-hemisphere-damaged patients with left neglect; right-hemisphere-damaged patients without neglect; and healthy, age-matched controls—Seki et al. (2010) found a significantly greater leftward deviation of the eyes relative to the midline in the neglect patients as compared with that characterizing the other groups. Seki et al. suggest that the greater leftward spatial placement of the eyes in a drawn face is a more sensitive indicator of unilateral spatial neglect than omitted details in a drawing.

Although there is a longstanding interest in neuropsychology in constructional apraxia, of which representational drawing is an example, there is a need for more fine-grained studies of graphic production in neurologically healthy individuals. Such studies would allow insight into the processes and mechanisms underlying graphic production which could in turn better inform the study of the cognitive neuroscience of drawing in brain-impaired populations.

1.2 *Asymmetries in profile drawing in brain-intact individuals*

The earliest controlled study of facial profile drawing was by Jensen (1952), who compared three groups of right handers from different geographic/linguistic backgrounds on this task. The groups were Americans, Norwegians (both of whom were left-to-right readers), and Egyptians (right-to-left readers). Participants were to draw a profile or side view of a human face. Jensen found an overall leftward-facing preference that was stronger in Norwegians than Americans (91% vs 76% leftward-facing profiles, respectively) and in Americans than in Egyptians (76% vs 66% leftward-facing, respectively). However, since even the right-to-left language group showed an overall leftward-facing bias in profile drawing, Jensen concluded that reading/writing habit was not likely to be the chief determinant of differences in profile orientation. In contrast to Jensen's results, other authors have found that reading/writing direction was the chief determinant of directionality of human facial profile drawings. For example, Vaid (1995) found that left-to-right readers of Hindi overwhelmingly drew leftward-facing facial profiles (89.1%), whereas right-to-left readers of Arabic did not show a preference for either leftward-facing or rightward-facing profiles (45.2% leftward facing).

Jensen (1952) also examined the role of handedness in profile drawing orientation, comparing the performance of 355 right handers with 33 left handers, all of whom were American. The results showed a significant leftward-facing bias among the right handers only (65% vs 42% for right handers vs left handers). Subsequent studies by Martin and Jones (1999) and by Picard (2009)—who compared right and left handers in adult and child populations, respectively—further noted an association between a leftward-facing drawing bias and right handedness.

1.3 *Theoretical accounts of spatial biases in figure drawing*

At least four different explanations of drawing direction have been put forth (see Vaid, 2011). The first, and most common, explanation is a *laterality account*, which proposes that directional tendencies have biological origins, specifically, relating to asymmetries in cerebral hemispheric functioning. Spatial processing is associated with right cerebral hemisphere specialization, and a right hemisphere superiority may lead to greater attentional resources directed to the left side of space. How cerebral laterality may in turn affect the direction of drawn figures is less clear, but some authors (eg Alter, 1989; Karev, 1999) have proposed that it does. For example, noting an overall leftward drawing preference for various objects, particularly among right handers, Karev (1999, page 430) concludes that "the simplest explanation of our results is to ascribe the findings concerning directionality to right hemisphere activation in drawing and to corresponding left attentional bias."

Another explanation is the *script directionality account*, which holds that individuals prefer a particular side of space or direction depending on their reading/writing direction (Nachshon, 1985; Vaid, 1995). In this view, individuals exhibit a bias in viewing and drawing objects that corresponds to the direction of reading and writing in their language. Right-to-left readers such as Arabic or Persian readers are expected to show a preference for scanning a scene from right to left, while left-to-right readers such as English or French readers are expected to show a left-to-right scanning bias (see Eviatar, 1997, for a meta-analysis). Vaid (1995) demonstrated that Hindi readers (left-to-right readers) showed a leftward bias in object facing, whereas Urdu readers (who were right to left readers but also knew Hindi, and were thus bidirectional) showed neither a leftward nor a rightward preference.

A third view proposed to account for directionality effects is a *biomechanical/chiral account*, which proposes that directionality is influenced by greater ease of outward-directed rather than inward-directed movements of the hands or limbs (Crovitz, 1962; van Sommers, 1984). In this account right handers and left handers should show opposite facing biases since outward-directed movements with the right hand would result in a left-facing figure, whereas outward-directed movements with the left hand would result in a right-facing figure.

Lastly, a *chiral/scriptal account* argues that reading/writing habits interact with biomechanical variables in influencing drawing directionality. Thus, the outward-directed movement preference associated with the biomechanical view would be reinforced in right handers by a left-to-right writing direction for readers of English; however, for left-handed English readers the two variables would have opposing influences. Similarly, among native readers of Arabic, Hebrew, or Urdu, a right-to-left reading/writing habit would be consistent with the biomechanical movement preference of left handers but not that of right handers.

It is not clear whether script direction or biomechanical principles exert a stronger influence when the two have opposing influences. Evaluating the contribution of each of these variables was the aim of our study.

1.4 *Present study*
Even though several studies of drawing directionality have accumulated over the past several decades, it is not clear whether there is a robust directional bias in object facing and the extent to which it is influenced by such variables as hand used to draw or the participant's reading/writing direction. The present study sought to address these questions through a meta-analytic investigation of directional biases in the facing of human facial profile drawing. There are by now 17 published studies and several unpublished studies of object facing with particular focus on the face. The present study is the first meta-analytic approach to the study of directionality of profile facing in figure drawing. Two separate meta-analyses were conducted. The first examined the relationship between handedness and facial profile drawing, and the second examined the relationship between script direction and facial profile drawing.

2 Method
2.1 *Literature search*
A literature search was conducted for all studies, published or unpublished, that examined profile drawing in relation to either handedness or reading/writing direction. All studies conducted through May 2014 were included. The keywords used for the handedness analysis were *handedness*, *face*, *drawing*, *facial*, *profile*, and *directionality*. The keywords used for the script direction analysis were *script direction*, *culture*, *reading*, *writing*, *systems*, *face*, *drawing*, *facial*, *profile*, and *directionality*. The keywords were searched through 8 electronic databases: PsycINFO-1872-current (CSA), Web of Science (ISI), MedLine (OVID), Academic Search Complete (Ebsco), OmniFile FT Mega (Wilson), ERIC, MLA International Bibliography, CAB Abstracts (OVID), and Science Direct (Elsevier). The database search enabled us to manually search by cited references. Specifically, the search was carried out using two-way citation checks—that is, by looking for whom those studies cited and who cited those studies. Next, the search was narrowed to an author name search. Then we communicated with as many of the authors as we could contact, which led to a few unpublished studies as well.

2.1.1 *Analysis of relation between handedness and profile facing direction.* The search methods initially yielded 23 primary studies. However, 7 had to be excluded (Alter, 1989; Alter, Rein, & Toro, 1989; Bolton, 1977; Crovitz, 1962; three samples of Martin & Jones, 1999; Roszkowski & Snelbecker, 1982; Vlachos & Bonoti, 2004). The excluded studies either did not provide data separately for facial profiles per se (Alter, 1989; Alter et al., 1989), did not code for face drawing direction (Vlachos & Bonoti, 2004), or did not provide actual percentage values in the reporting of their results for each group (eg Bolton, 1977; Crovitz, 1962). In the end, our analysis of handedness and profile drawing direction was based on 19 eligible primary studies[1] with 27 independent samples (see summary in table 1).

2.1.2 *Analysis of relation between script direction and profile facing direction.* The search methods described above yielded 9 primary studies with a total of 10 samples in which the facial drawing performance of left-to-right and right-to-left readers was compared[2] (see table 2 for the effect sizes of the samples including both left-handed and right-handed participants and table 3 for the effect sizes of the samples consisting of only right-handed participants).

[1] The studies included in the meta-analyses are indicated with a bullet in the reference section.

[2] Although initially 25 studies were found, most tested readers with only one type of script direction. Therefore we had to exclude those studies from the analysis.

Table 1. Samples included in meta-analysis of facial profile drawing that noted handedness in relation to profile direction (including left-to-right and right-to-left readers).

Study	Sample	Right handers		Left handers		Total sample size	Effect size	Corrected *r*	Group[a]
		% left-facing	*n*	% left-facing	*n*				
Jensen (1952)	1	65	355	42	33	388	−0.13	−0.23	AM
Levy & Reid (1978)	2	83.33	24	33.33	24	48	−0.51	−0.51	AM
Shanon (1979)	3	77.5	40	47.5	40	80	−0.31	−0.31	AM
	4	85	40	40	40	80	−0.47	−0.47	IS
Scheirs (1990)	5	50	157	55	16	173	0.03	0.05	DU
Richardson (1992)	6	64	128	58	19	147	−0.04	−0.06	AM
Karev (1999)	7	92.42	264	70.24	270	534	−0.28	−0.28	BU
Martin & Jones (1999)	8	57.4	166	38.5	110	276	−0.18	−0.19	BR
	9	65	283	48.9	186	469	−0.16	−0.16	BR
De Agostini & Chokron (2002)	10	71	77	53	45	122	−0.18	−0.19	FR
Vaid (2005)	11	39.8	84	38.5	13	97	−0.01	−0.01	AM
Vaid (2006)	12	47.9	73	50	12	85	0.01	0.02	AM
Viviani (2006)	13	56.3	598	48.4	62	660	−0.05	−0.08	IT
Vaid (2007)	14	69.7	33	50	2	35	0.10	0.21	H-U
Vaid & Chen (2009)	15	46.32	136	42.17	83	219	0.04	0.04	AM
	16	45	80	50	22	102	0.04	0.05	AM
Picard (2011)	17	80	20	50	20	40	−0.31	−0.31	IT
	18	40	20	40	20	40	0.00	0.00	IT
	19	65	20	45	20	40	−0.20	−0.20	IT
Rhodes (2010)	20	57.5	34	26.3	28	62	−0.40	−0.40	AM
	21	68.2	7	25	3	10	−0.52	−0.55	AR
Vaid (2010)	22	58.82	17	80	5	22	0.18	0.22	AM
Vaid & Eslami (2010)	23	76	25	80	5	30	−0.04	−0.05	AR
Vaid, Lopez, & Tosun (2011)	24	37.3	83	38.7	31	114	−0.01	−0.01	AM
	25	37.3	150	34.6	52	202	0.02	0.03	AM
	26	57.1	14	50	2	16	0.05	0.07	AM
Liew & Vaid (2012)	27	32	53	41	27	80	−0.09	−0.09	AM

Note: Corrected effect size represents the effect size after uneven sample size was corrected.
[a]AM, American; AR, Arab; BR, British; BU, Bulgarian; DU, Dutch; FR, French; H-U, Hindi-Urdu, IS, Israeli; IT, Italian..

2.2 *Procedure*

For each study the percentage of leftward-drawn faces was examined in relation to participant handedness and script direction. In addition, the country of residence of participants was coded. In addition to the first author, a research assistant who was not familiar with the rationale of the study coded all the studies using the same coding description sheet. Interrater agreement was 100% for overall facial profile direction, 99% for facial direction in relation to handedness, and 100% for facial direction in relation to nationality and script direction.

2.2.1 *Analysis of relation between handedness and facial profile drawing direction.* For each study, 2 (left handers vs right handers) × 2 (leftward vs rightward face) χ^2s were computed. Then, in order to compute effect sizes, χ^2 results were converted to a Pearson correlation coefficient using the following formula: $(\chi^2)^{-1/2}/\text{total sample size}$.

Table 2 . Samples included in meta-analysis of script direction and facial profile direction (including right handers and left handers).

Study	Sample	Left-to-right readers		Right-to-left readers		Total sample size	Effect size	Correc-ted *r*	Group[a]
		% left-facing	*n*	% left-facing	*n*				
Jensen (1952)	1	76	398	66	90	488	0.09	0.12	AM-EG
Shannon (1979)	2	62.5	80	62	80	160	0.01	0.01	AM-IS
Vaid (1995)	3	89.1	55	45.2	82	137	0.45	0.45	HI-AR
Vaid & Chen (2009)	4	43	219	46	50	269	–0.02	–0.03	AM-AR
	5	46.08	102	64.71	17	119	–0.13	–0.18	AM-UR
Rhodes (2010)	6	43.55	62	60	10	72	–0.11	–0.16	AM-AR
Vaid & Eslami (2010)	7	63.63	22	66.66	24	46	0.03	0.03	AM-AR
Vaid & Eslami (2011)	8	37.77	62	76.66	30	92	–0.37	–0.39	AM-AR
Kebbe & Vinter (2013)	9	70.8	60	32.3	60	120	0.38	0.38	FR-SY
Vaid & Eslami (2012)	10	54.8	31	50	18	49	0.05	0.05	AM-AR

[a]AM, American; AR, Arab; EG, Egyptian; FR, French; HI, Hindi; IS, Israeli; SY, Syrian; UR, Urdu.

Table 3. Samples included in meta-analysis of script direction and facial profile direction.

Study	Sample	Left-to-right readers		Right-to-left readers		Total sample size	Effect size	Correc-ted *r*	Group[a]
		% left-facing	*n*	% left-facing	*n*				
Shannon 1979)	1	77.5	40	85	40	80	0.10	0.10	AM-IS
Vaid (1995)	2	89.1	55	45.2	82	137	0.45	0.45	HI-AR
Vaid & Chen (2009)	3	46.32	136	46	50	186	0.00	0.00	AM-AR
	4	45	80	64.71	17	97	–0.15	–0.20	AM-UR
Rhodes (2010)	5	57.5	34	68.2	7	41	0.10	0.13	AM-AR
Kebbe & Vinter (2013)	6	70.8	60	32.3	60	120	0.38	0.38	FR-SY
Vaid & Eslami (2012)	7	54.8	30	50	18	48	0.05	0.05	AM-AR
Vaid, Eslami, Tosun, & Lopez (2011)	8	58.82	17	66.66	24	41	0.08	0.08	AM-AR
Vaid & Eslami (2011)	9	37.77	62	76	25	87	–0.35	–0.38	AM-AR

[a]AM, American; AR, Arab; FR, French; HI, Hindi; IS, Israeli; SY, Syrian; UR, Urdu.

After computing the effect sizes, using the formulas provided by Hunter and Schmidt (2004, page 280), uneven sample sizes were corrected individually. The correction was needed because all studies except three had a far greater number of right than left handers. Using the correction, it was possible to estimate what the correlations would be if sample sizes of left and right handers had been equal (see table 1). After correcting for uneven sample sizes, the Hunter and Schmidt meta-analysis method was used to compute the mean correlation as well as the variability of the corrected correlation.

Following Hunter and Schmidt's guidelines, if the variability in correlations across studies accounted by for statistical artifacts was less than 75%, it was reasonable to expect that there is an effect of some moderator. For that reason, for each relationship in which artifacts accounted for less than 75% and the corrected variability was large enough to expect moderators, moderator analyses were carried out until confounding variable(s) were discovered. These analyses were done using the same procedure as in the overall meta-analysis.

2.2.2 *Analysis of profile drawing direction in relation to script direction.* For the script direction analysis 2 (left-to-right readers vs right-to-left readers) × 2 (leftward vs rightward face orientation) χ^2s were computed. The same formula as in the handedness analysis was used to convert the χ^2 results to effect sizes. Uneven sample sizes were corrected for script direction analysis because for half of the studies the number of right-to-left readers was far less than left-to-right readers. After correcting for unequal sample sizes, the same analysis as noted above for handedness was conducted to compute mean correlation, standard deviation, and percentage variance attributed to artifacts.

3 Results

3.1 *Facial profile drawing in relation to handedness*

The results of the analyses for handedness, including moderator analyses, are reported in table 4 and figure 1. A total of five different analyses were carried out. The first analysis included all the samples in table 1—that is, samples that differed in script direction as well. After correcting for uneven sample size and sampling error, it was found that there was a negative medium-sized relationship (–0.17) between handedness and facial profile drawing direction, indicating that right handers tend to draw leftward-oriented faces while left handers drew rightward-oriented faces. Variability, however, was relatively high. Artifacts (uneven sample size in this case), sample size, and sampling error were able to explain 39.52% of the variance. The rest of the variance (60.48%) remained unexplained. Therefore, a second analysis was done in which right-to-left readers (three samples) and bidirectional readers (one sample) were removed and the analysis was conducted on only left-to-right readers (see table 4 and figure 1).

The analysis of only left-to-right reader samples demonstrated a negative correlation (–0.16) between handedness and profile direction, as was found in the previous analysis. The magnitude of the correlation, however, decreased compared with the overall analysis. The standard deviation decreased as well. Interestingly, uneven sample size and sampling error were able to explain more of the variance (41.07%) than in the overall analysis after excluding right-to-left readers, although the percentage variance is still low. This demonstrates that

Table 4. Meta-analytic results: relationship between handedness and face direction.

Analysis	N	k	r	SD_r	ρ	SD_ρ	CV_{10}	CV_{90}	%var	CI_L	CI_U
Overall	4171	27	–0.11	0.13	–0.17	0.11	–0.32	–0.03	39.52	–0.21	–0.14
Left-to-right samples	4016	23	–0.10	0.12	–0.16	0.10	–0.30	–0.03	41.07	–0.20	–0.13
American samples	1662	14	–0.04	0.13	–0.09	0.15	–0.27	0.10	37.53	–0.14	–0.03
European samples	2354	9	–0.15	0.09	–0.21	0.01	–0.22	–0.19	97.07	–0.25	–0.16
Right-to-left samples	155	4	–0.28	0.18	–0.43	0.00	–0.43	–0.43	100.00	–0.58	–0.28

Notes: r = mean sample-size-weighted correlation; ρ = mean corrected correlation; CV_{10} and CV_{90} = 10% and 90% credibility values, respectively; CI_L and CI_U = 95% confidence intervals for lower and upper bounds, respectively; %var = percentage of variance attributable to artifacts.

script direction is one of the moderators. Since the standard deviation was large and the percentage of variance attributable to artifacts was low, it is possible that the data were influenced by other moderators.

We observed that, of the twenty-three samples of left-to-right readers, fourteen came from the United States and nine from European countries—namely Italy, France, Bulgaria, and the Netherlands. Thus, two further analyses were conducted in which the data from the American and European samples were examined separately.

The results of the analysis of handedness and facial profile direction in the American-only samples showed a correlation of –0.09, indicating a very weak correlation. Further, given that the credibility interval includes zero (ranging from –0.27 to 0.10), the negative correlation cannot be considered as consistent over the entire American samples. In addition, the percentage of variance attributable to artifacts was 37.53%, while the standard deviation was 0.15. Thus, removing the European samples made the correlation weaker and decreased the variance attributable to artifacts.

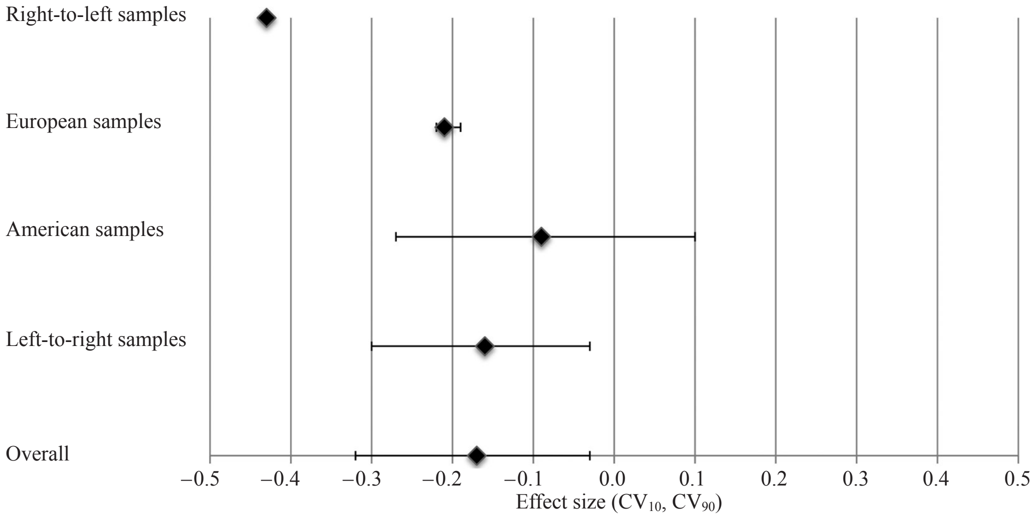

Figure 1. Forest plot of data demonstrating the effect size of handedness and direction of facial profile drawings separately for different script direction groups.

On the other hand, the analysis of handedness and profile facing direction in the European samples revealed a more consistent pattern. The mean corrected correlation increased to –0.21, while the standard deviation decreased to 0.01. Although the strength of the correlation is medium, the upper and lower boundaries of the credibility interval[(3)] do not include zero. Therefore, we can be confident that the negative correlation is consistent, and indicates that left-handed people in general tend to draw more rightward-looking faces and right-handed people draw more left-looking faces. Most importantly, correction of uneven sample sizes and sampling error explained 97.07% of the variance of the European sample.

A final analysis examined the relationship of face drawing direction and handedness in readers whose primary written language was from right to left. There were only four samples with right-to-left readers. The analysis revealed a strong negative correlation (–0.43) between handedness and facial profile direction in right-to-left readers. Moreover, the corrected standard deviation of right-to-left readers dropped to zero, and the percentage variance attributable to artifacts of right-to-left readers' analysis explains all of the variance (100%). Thus, we can

[(3)] Credibility values follow Bayesian credible intervals of θ as a random variable. Thus the concept of probability is invoked after observing the data, unlike the frequentist confidence interval, which treats θ as fixed.

be confident that the correlation is robust, and indicates that right-handed right-to-left readers tend to draw profiles facing leftward, whereas left-handed right-to-left readers tend to draw them facing rightward.

To summarize, the overall analyses demonstrated a negative correlation between handedness and face direction. This relationship was strong among right-to-left readers and European left-to-right readers. The percentage of variance was above 75% for the European samples and the right-to-left readers, which suggests there were no more moderators affecting their results. By contrast, the performance of American left-to-right readers showed high variability. It is not clear what may be underlying the higher variability on the part of the American sample.

3.2 *Facial profile drawing in relation to script direction*

The results of the analyses of script direction and facial profile direction are shown in table 5. Two different analyses were conducted. The first analysis included both left-handed and right-handed participants. A weak positive relationship was found between script direction and face direction of the profile drawings, suggesting that left-to-right readers tend to draw more left-looking profiles while right-to-left readers draw more right-looking profiles. However, the credibility interval included zero (ranging from –0.22 to 0.41), which means that this positive relationship was not consistent throughout the entire samples. Further, the percentage variance attributable to artifacts was too low (14.83%) and standard deviation was too high (0.24) to explain the variance with uneven sample size and sampling error. Thus, there are possible moderators influencing the variance.

Table 5. Meta-analytic results: percentage leftward facial profile drawing in relation to script direction.

Analysis	N	k	r	SD_r	ρ	SD_ρ	CV_{10}	CV_{90}	%var	CI_L	CI_U
Overall	1552	10	0.03	0.19	0.10	0.24	–0.22	0.41	14.83	0.03	0.16
Right handers	837	9	0.09	0.25	0.15	0.26	–0.18	0.47	15.51	0.08	0.22

Notes: r = mean sample-size-weighted correlation; ρ = mean corrected correlation; CV_{10} and CV_{90} = 10% and 90% credibility values, respectively; CI_L and CI_U = 95% confidence intervals for lower and upper bounds, respectively; %var = percentage of variance attributable to artifacts.

The second analysis was conducted to examine whether handedness was one of the moderators. Since the majority of the samples were based on right handers alone, we excluded left handers from the new analysis. This analysis revealed a stronger positive relationship between script direction and face direction (0.15). However, the credibility interval still included zero. In addition, the explained variance did not change very much (15.51%), while the standard deviation increased to 0.26. Therefore, we can conclude that, although handedness explained some of the variance, it did not capture most of it and we would need to look for other moderators such as other differences besides script direction. These could include cultural differences in drawing instruction, differential exposure to certain kinds of media representations of faces, or demographic variables related to age, gender, etc. However, owing to the limited number of samples, it was not possible to identify or test for other moderators.

4 Discussion

4.1 *Relationship between handedness and facial profile drawing direction*

The handedness and facial profile direction analysis demonstrated that there was a weak negative correlation between the variables: left handers tend to draw a rightward-oriented face, while right handers tend to draw a leftward-oriented face. However, the numbers may not be reflecting the true correlation coefficients because a problem in many handedness studies is the relative underrepresentation of left-handed participants in the sample. Hunter and Schmidt's meta-analysis method provides a way of correcting for uneven sample sizes. As is clear from table 1, the largely uneven differences in sample size that typically occur in studies that compare right and left handers are a considerable effective attenuation factor of handedness in the present study.

After correcting for uneven sample sizes of left and right handers, we found a negative medium correlation between handedness and face direction. This suggests that one of the factors that prevents, or makes difficult, knowing the true relationship between handedness and profile facing direction is the fact that there are considerably fewer numbers of left-handed participants in most studies. However, unexplained variance still remained after correcting for uneven sample size and sampling error. Additional analysis to discover possible moderator factors revealed that European samples showed a stronger negative correlation and a sufficient amount of percentage variance explained after accounting for uneven sample size and sampling error, but American samples still showed a sufficient amount of unexplained variance. This finding suggests that there may be other moderators even among groups with a similar script direction (eg drawing instructions in schools) that may influence the relationship between handedness and drawing direction.

In future work it will be important to explore other potential sources of unexplained variance. As suggested by Vaid (2011) and noted by van Sommers (1984), possible variables worth examining are drawing starting location (on the paper, and on the object), the axis of the response sheet (horizontal or vertical), and the shape of the frame in which the drawing is to be made (square or a rectangular shaped). Framing has been observed to affect aesthetic judgments and could well affect processing and production of drawn figures as well (eg Burton & Levy, 1991). In addition, cultural factors such as the degree of experience with using one's hand to write (versus using a computer keyboard) or cultural differences in figure drawing conventions may be important to quantify in future work.

The analysis of right-to-left readers' drawings, on the other hand, revealed the strongest relationship out of all three groups (American left-to-right readers, European left-to-right readers, and various right-to-left readers), and all of the variance in this group was explained by sampling error and uneven sample size. The strong relationship is all the more remarkable given that it was based on only four samples. The samples were drawn from speakers of the following languages: Arabic, Hebrew, and Urdu. We do not have a ready explanation for why this group showed such a robust influence of handedness on profile drawing direction.

In future research it will be important to obtain more samples from American settings. Given that the present meta-analysis was based on all existing studies related to handedness and drawing facial profile direction, the results of the American samples are at present inconclusive.

4.2 *Relationship between script direction and facial profile drawing direction*

Even though we had a limited number of independent samples, we were able to correct for uneven sample size and sampling error. Overall, left-to-right readers demonstrated a tendency to draw leftward-oriented faces, while right-to-left readers demonstrated a tendency to draw rightward-oriented faces. However, the relationship was not strong or consistent for each sample. In fact, right-to-left readers showed a leftward-orienting tendency half of the time. This resulted in a large amount of unexplained variance. Handedness could have been a possible moderator—thus, we subsequently analyzed only right handers. Although the analysis revealed a stronger relationship, the amount of unexplained variance did not change significantly and inconsistency between samples remained.

Overall, the results of the script direction analysis showed that the relationship between script direction and profile drawing direction is not as consistent as that between handedness and drawing direction. Further, the script direction analysis revealed almost 80% of unexplained variance. This strongly indicates the need for more studies on script direction—specifically, studies that directly compare two different script directions.

4.3 *Concluding comments*

The meta-analysis allowed us to test the competing predictions of the biomechanical/ chiral account and script directionality view. The findings suggest that handedness is an important factor influencing facial profile direction, although the effect size is not large. In particular, right handers tend to draw profiles facing leftward. However, left handers do not always show a rightward-facing tendency. This might be because left handers have had to adjust to a right-handed world.

Further, the direction of facial profiles did not reveal a consistent effect of reading/ writing direction despite findings from individual studies showing a strong script direction bias in perceptual and aesthetic judgments as well as in drawing of objects such as vehicles or animals (eg Vaid, 1995). It is possible that profiles are a special category of drawn objects that are singled out in drawing instruction and that across different parts of the world there may be different conventions about starting location or stroke movement trajectories in profile drawing. For example, the personal experience of the second author may be instructive here. In her experience a particular shorthand strategy was used to teach children in north India how to draw a profile of a face, using numbers: one starts with the numeral '1', which would correspond to the forehead. This would be followed by writing the number 6 attached below the 1, to correspond to the nose; then write the number 3 below the 6, which would correspond to the mouth; and then complete the figure with a counterclockwise circular motion. This strategy would result in consistent leftward-looking profiles and could account for the finding by Vaid (1995) of a strong leftward bias in face drawing not only by the Hindi readers but also by the Urdu readers (recruited in north India). Of course, it is not possible to know if participants were using this or any other ad hoc strategy. In future work it will be important to monitor these more fine-grained aspects of the drawing process to uncover clues about the source of differences observed across groups. Finally, the weak effect of script direction in the present study may also in part reflect the fact that the majority of the right-to-left readers were also exposed to and in some cases fluent in left-to-right written languages and are thus more properly characterized as bidirectional readers/writers.

Taken together, the findings from the two meta-analyses are consistent with the *bio-mechanical account* inasmuch as performance of both left-to-right and right-to-left readers was affected by the direction of hand movement in drawing (related in turn to hand used to draw). However, an interaction of biomechanical and scriptal influences may also be at work. Since the majority of the studies tested did not include all combinations of handedness and script direction, it is difficult to evaluate the interaction hypothesis. In particular, studies of script direction have had very few left-handed participants. In order to adequately test the interaction of script direction and handedness, more studies are needed to test both variables under the same conditions.

Further, our results suggest that there are some cultural factors affecting the consistency of the drawing direction tendency. The European samples demonstrated a stronger relationship between handedness and script direction than did the American samples, although both groups share the same script direction. What the precise nature of these cultural factors may be (eg differences in the amount of experience in using the hand to write/draw, or in formal instruction in drawing faces) remains to be identified in further work.

Taken together, the results of two meta-analyses of existing studies of profile drawing direction in neurologically healthy individuals showed that the direction in which profiles end up facing depends both on whether the right or the left hand is used to draw and (to a lesser extent) on whether one is exposed primarily to a left-to-right written language or to both left-to-right and right-to-left languages.

In terms of underlying mechanism, we believe that while there may well be some contribution of cerebral hemisphere differences in visuospatial functioning, performance in graphic production tasks is more parsimoniously explained with reference to ease of execution of certain movements, in turn reflecting biomechanical and cultural influences. That is, biomechanical principles lead one to perform outward-directed movements more easily than inward-directed movements. Further, given that the front of an object tends to be drawn first (in drawing a profile of a face one typically starts with the forehead and proceeds downward to the nose, as observed by Crovitz, 1962, and by van Sommers, 1984), depending on whether one is using the right or the left hand to draw, the profile will end up facing leftward or rightward, respectively. This is what our meta-analysis revealed. Interestingly, the tendency of right handers to face profiles leftward and of left handers to face them rightward was found irrespective of whether the participants were readers of left-to-right or right-to-left languages.

Two somewhat puzzling findings included the existence of variability among the left-to-right readers and a relative lack of variability (ie a robust handedness effect) among right-to-left readers, despite the fact that the latter group had far fewer participants than the former group. With respect to the latter finding, we offer the following speculation. For right-to-left readers/writers a robust effect of handedness on profile facing direction may reflect a joint effect of two different movement direction biases: the biomechanical tendency for a preference for outward-directed movements (which, as already noted, would lead to different facing biases depending on the hand used to draw) enhanced by a cursive writing-related stroke movement bias arising from prolonged experience in writing Arabic or Urdu. Specifically, we note that there are many more letters in these languages compared with languages like English that require a downward stroke movement direction. Thus, right-to-left readers may be more inclined (than left-to-right readers) to draw profiles in a direction starting from the forehead and proceeding downward because of this habitual downward stroke direction when writing in Arabic/Urdu; readers of left-to-right languages may show more variability in their stroke sequence when drawing faces. For right-to-left readers a tendency for a downward stroke movement coupled with a preference for movements directed away from the body would result in a strong left-facing bias when the right hand is used to draw a face and a right-facing bias when the left hand is used. Of course, this explanation would need to be directly tested by comparing the actual direction of strokes produced by left-to-right and right-to-left readers when drawing profiles.

More generally, our findings based on graphic production in neurologically healthy individuals varying in hand dominance and language experience provide important normative data that can inform interpretation of drawings produced by brain-damaged individuals. At a minimum, our meta-analytic findings revealed the importance of hand used in affecting object facing direction. We argue that figure drawing direction is determined largely by biomechanical principles related to ease of execution of different types of limb movements (see also Martin & Jones, 1999; van Sommers, 1984, 1989). Whatever the contribution of the two hemispheres to face recognition, at least when it comes to drawing a face in side view, what appears to determine how one orients the face in space depends on handedness. Handedness here is a proxy not for cerebral dominance but for motoric principles affecting the relative ease of execution of certain types of movements in space.

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