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Luria's fist-edge-palm test: A small change makes a big difference

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ABSTRACT

Slight modifications in the instructions or administration of neuropsychological tests could result in noticeable differences in performance. A good example is offered by a test devised by Luria to assess executive functioning in motor planning, the three-step fist-edge-palm (FEP) test, which is still frequently employed in clinical settings and features in several neuropsychological test batteries such as the Frontal Assessment Battery (FAB). While Luria described the orientation of the fist as horizontal to the testing desk (hFEP), recent versions of the task indicate the fist should be vertical to the testing desk (vFEP). The current study examined whether administering the hFEP or the vFEP tests results in different performance in healthy people, and whether one version is better than the other at detecting impairments in a patient population. The hFEP proved more challenging for healthy adults than the vFEP, and people with brain damage committed more errors on the hFEP than the vFEP. Both versions correlated with executive measures but also with several other cognitive variables, indicating that the test is not a specific marker of executive functions. Although performance on the FEP is sensitive to articulatory suppression, faster pace, and the number of sequences performed, none of these conditions fully account for the differences between the hFEP and vFEP. The additional demand of the hFEP appears to be due to the less natural (i.e., automatic) orientation of the horizontal fist. In conclusion, a small change in the administration of the test, eluding Luria's instructions, grossly modified its sensitivity. Clinicians and researchers should be wary of modifying instructions or testing procedures without considering the possible consequences of such modifications.

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1. Introduction

1.1. *The fist-edge-palm test as a "Frontal" assessment measure*

Aleksandr devised several tests to assess executive functioning in motor planning (Luria, 1966). One such test is the three-step fist-edge-palm (FEP) test (Luria, 1966, pp. 332–334). Luria associated impairment on this test with one aspect of what he labelled the Frontal Lobe Syndromes [note the plural] (Luria, 1969). The test asks participants to execute a sequence of three hand positions multiple times repeating the correct order of presentation. Correct performance requires fine grain coordination, attention, planning, monitoring, updating, and inhibition. Luria's proposal of the FEP test as a means to assess executive functions was based upon his clinical observations of patients such as case "Zav", a 43-year-old woman with a left frontal meningioma (Luria et al., 1964). Zav had no problems in reproducing single movements or in understanding the task instructions but failed to reproduce ordered sequences of movements (Luria et al., 1964).

The usefulness of the test in detecting the effects of frontal lobe damage has been confirmed by anecdotal observations (Milner, 1964), but later criticised by carefully investigated single cases and group studies (Canavan et al., 1985) suggesting that the relationship between failing the FEP test and lesions in the frontal lobes was not strong. Executive functions do not necessarily relate to specific anatomical structure (Chan et al., 2015). There are many ways of performing or failing cognitive tasks. Indeed, poor performance on such tasks says little about the locus of the patient's lesion and more about the impairment or sparing of their cognitive abilities (MacPherson & Della Sala, 2015, p. 20). One has to be wary of the illusion of "purity" in cognitive tasks (Cubelli, 2019). Luria himself was very aware of the pitfalls of proposing a one-to-one relationship between a test and a cerebral area. In the very first manuscript published by *Cortex*, Luria maintained that "… a higher (mental) function may suffer as a result of the destruction of any link which is a part of the structure of a complex functional system and, consequently, may be disturbed even when centres differ greatly in localisation" (Luria, 1964, p. 6). Later he also queries the specificity of the FEP as an indicator of frontal damage (see Bowen, 1989).

Notwithstanding its neuroanatomical inaccuracies, the FEP test has been widely used both in clinical settings and in research studies to identify executive dysfunctions. However, subsequent versions of the test have departed from the original version described by Luria, undermining its experimental use and clinical value. Luria advised that the fist pose should be horizontal; however, later work and test batteries that have included the FEP test have presented the fist in a vertical pose. In this study, we aim to analyse the consequences of this later modification with a view to reconciling some of the apparent contrasting findings gleaned from the literature.

1.2. *Orientation of the fist in the FEP test*

In his main oeuvre, the *Higher Cortical Functions in Man* (1962; English version 1966), Luria states that when performing the FEP "… the patient either loses the correct sequence of poses or continues to repeat the previous pose (for example, the fist) or the previous position in space (for example, a *horizontal fist* pose is followed by a horizontal palm pose) inertly" (Luria, 1966, pp. 332–333). Indeed, in Figure 99 (p. 334 – Fig. 115 in the Russian version), the fist is illustrated in a horizontal pose.

Luria made earlier references to the FEP test in the Russian version of his book on *Traumatic Aphasia* (Luria, 1947, p. 194) whereby he refers to the dissertation of Evgenya G. Skolnik-Jarros entitled, "Movement disorders in case of damage to premotor systems" (1945) where the test was originally reported. There, Figure 46 (p. 194) clearly shows the fist in a horizontal pose. The same figure appears as Figure 55 in Chapter 10 (The Investigation of Non-Verbal Functions: Gnosis and Praxis From the book Traumatic Aphasia) of the English version of *Traumatic Aphasia* (Luria, 1970, p. 276). Here, Luria (1970, p. 275, footnote 9) reveals a detailed description of the FEP test, which is provided by Skolnik-Jarros (1966) in a book chapter edited by Luria and his colleague Evgenia D. Homskaya (Luria & Homskaya, 1966), who would later produce a biography of Luria (Homskaya, 2001). Skolnik-Jarros then left neuropsychology to study the neuroanatomy of the retina.

Luria's description of the sequence of three hand poses (1947, 1962, 1966, 1970) of the FEP test is not always the same, but invariably the fist pose is performed first and the fist is always placed horizontally on the table (see Fig. 1). This is how the test is also described in later textbooks (e.g., Henderson, 2010, p. 248, Fig. 17.7; London, 2010, p. 20 Fig. 1.8).

However, more recently, authors have described the orientation of the fist as "vertical". Notably, this is how the FEP test is administered within the FAB (Frontal Assessment Battery – Dubois et al., 2000).[1] Influenced by the

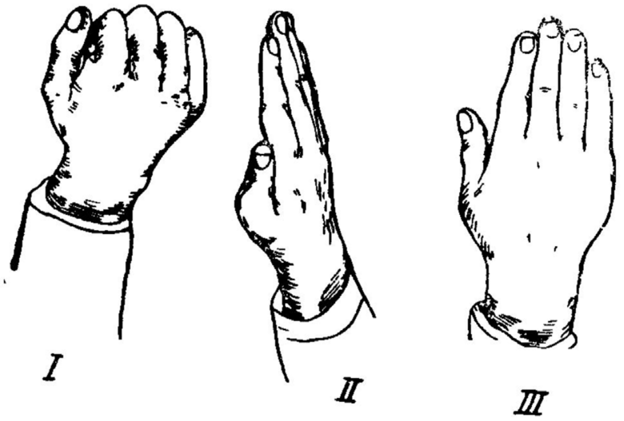

Fig. 1 – Illustration of the three hand positions in the Fist-Edge-Palm test as depicted by Luria on Fig. 115 of the Russian version of his *Higher Cortical Functions in Man* (Luria, 1962). The fist is presented first and placed horizontally on the table.

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[1] See formal instructions on how to administer the FAB: https://www.youtube.com/watch?v=dJ0ubrh1ack, from minute 2.45; see: https://www.psychdb.com/_media/frontal_fab_scale.pdf; see also: https://www.psychdb.com/neurology/neuro-exam/luria.

widespread use of the FAB (Hurtado-Pomares et al., 2018), the vertical orientation of the fist has become embedded in test batteries (e.g., Daffner et al., 2015; Japanese KABC-2 Publication Committee, 2013; Wonse et al., 2017) and widely used in clinical settings. In other test batteries, the orientation of the fist is not made precise (Torralva et al., 2009); in further instances, both versions of the FEP (with horizontal or vertical fist) are reported (Arciniegas, 2013, p. 378, Fig. 23.7).

The interchangeable use of the two versions of the FEP has resulted in contradictory findings within clinical populations (Economou et al., 2007; Fernández-Fleites et al., 2021; Goh et al., 2019; Weiner et al., 2011). Different average scores have been reported in otherwise similar control samples (Canali et al., 2007; Lima et al., 2008; Terada et al., 2017) and different neural correlates have been identified in neuroimaging studies (Chan et al., 2006; Kobayashi et al., 2021; Umetsu et al., 2002).

1.3. *Factors influencing the performance on the FEP*

Performance on the FEP test is not influenced by age or gender; however, it is affected by lower levels of education so that even people with no executive deficit score pathologically (Nitrini et al., 2005).

Luria and his collaborators presented the FEP as a nonverbal test; however, they acknowledged that participants may use language as a strategy to better perform the task. Skolnik-Jarros (1966) noticed that errors increased when participants “were pinching their tongue to minimise rehearsal” (p. 330). Indeed, Frencham et al. (2003) and Mitsuhashi et al. (2018) showed that successful performance likely involves the use of verbal processing, as it is specifically disrupted by articulatory suppression. Moreover, Varkovetski et al. (2020) indicated that the speed of presentation might modulate performance on the FEP test (see also Kobayashi et al., 2021). Whether articulatory suppression or speed of presentation have a differential effect on the two versions of the FEP remains unexplored.

Skolnik-Jarros (1966), p. 330) also observed that performance on the FEP was modulated by the pace of its administration.

1.4. *Aims of the study*

The current study aimed at (i) investigating whether administering the FEP test with the horizontal version of the fist, as originally proposed by Luria (1966), or with the vertical version of the fist, as instructed by recent adaptations of the test in the wake of the FAB (Dubois et al., 2000), results in different performance in healthy people; (ii) assessing which version better detects impairments in a patient population; (iii) verifying the correlations of either versions of the FEP with other neuropsychological tests, including executive measures; (iv) exploring the extent to which either version of the FEP test is affected by articulatory suppression or by faster pace of presentation. To this end, healthy older participants and a group of people with brain damage were administered the two versions of the FEP under different experimental conditions.

2. Methods

We report how we determined our sample size, all data exclusions, all inclusion/exclusion criteria, whether inclusion/exclusion criteria were established prior to data analysis, all manipulations, and all measures in the study.

2.1. *Participants*

2.1.1. *Pilot study: Healthy younger adults*

A group of 63 younger adults (mean age = 24.3 years, SD = 2.9; mean education = 17.2 years, SD = 2.6; 50 women) was tested as an initial pilot study to examine the effects of articulatory suppression and faster pace (see Experimental procedures below).

2.1.2. *Main study: Healthy older adults*

A total of 31 older (mean age = 71.9 years, SD = 8.8, range = 59–92; years of full-time education = 11.1, SD = 5.5, range = 5–23; 19 women) participants took part in the experiment. They were recruited among the carers of the patients who were available and willing to be tested. None had to be excluded. They had a mean Mini-Mental State Examination (Measso et al., 1993) score of 28.52 out of 30 (SD = 1.46, range = 25–30).

2.1.3. *Main study: People with brain damage*

The sample was a time-determined (six months) continuous series of 67 (30 women) people attending the Clinical Neuropsychology Service at the Somma Lombardo Hospital for formal assessment who agreed to take part in the experiment. The only exclusion criteria were inability to understand instructions and unwillingness to participate. The participants were affected by brain damage due to different aetiologies (stroke = 29, haemorrhage = 8, brain injury = 6, Mild Cognitive Impairment = 3, Alzheimer's disease = 6, frontotemporal dementia = 3, vascular dementia = 11, multiple sclerosis = 1: mean age = 71.2 years, SD = 10.2, range = 38–84; education level = 8.8 years, SD = 3.7, range = 3–19).

2.2. *Experimental procedures*

During the pilot and main experimental sessions, participants were asked to perform both versions of the FEP (hFEP and vFEP) with their preferred hand six times. Half the participants started with the hFEP, the other half with the vFEP. For each FEP, the total score ranged from zero to a maximum of six. Errors were recorded and categorized into wrong fist orientations (vertical fist formed during a horizontal sequence or a horizontal fist formed during a vertical sequence) or sequence errors (missing hand positions or mistakes in the sequence order). The experimental session was preceded by a practice example (imitating the examiner performing both versions of the FEP three times).

In the pilot study, younger adults also performed the FEP test with articulatory suppression (AS; counting backwards starting from 101) and at a faster pace (in time with a metronome at 180 bpm cf. 60 bpm in the normal condition). In the main study, older adults performed the same conditions as the pilot study but also performed a more cognitively demanding AS condition (high demand articulatory suppression – HDAS) where they had to count backwards in 3s starting from 101. The order of the experimental conditions (normal, AS, HDAS and fast paced) were randomised across individuals.

Before the main experimental session, the patients were assessed with a background neuropsychology battery (see Table 3). They were also administered the entire Italian version of the FAB (Appollonio et al., 2005). Given the study's aims and predictions, and assuming that proactive interference could influence the FEP, the FAB was administered first with the hFEP, and then with the vFEP.

2.3. *Statistical analysis*

The statistical analyses were carried out using R version 4.2.2. For the analysis of the pilot data with younger adults, performance on the hFEP and vFEP was compared across the different conditions using separate independent samples t-tests. Shapiro–Wilk tests demonstrated that the data for the older and brain damaged groups on the demographic and experimental measures were often not normally distributed (*ps* > .05). Aligned rank transform (ART) ANOVAs (Wobbrock et al., 2011) were conducted on the ranked data in R for the older group performing the experimental conditions using the package *ARTool* to allow examination of the interaction as well as the main effects. For the people with brain damage data, correlational analyses between age and education and the FEP test measures were conducted using Spearman Rank Correlation tests. Mann–Whitney U tests examined differences between gender and the FEP test measures. Wilcoxon signed-rank tests compared performance on the hFEP and vFEP versions. Correlational analyses between the background neuropsychological measures and the correct sequence scores were conducted using Spearman Rank Correlation tests and the False Discovery Rate (FDR) was applied to reduce the likelihood of Type-I familywise error. Mann–Whitney U tests examined differences between gender and the FEP test measures. Finally, we subdivided our people with brain damage into those who were cognitively impaired and those who were cognitively unimpaired on the different background neuropsychological tests. These data were not normally distributed and the ART procedure could not be correctly applied. Therefore, we compared patients' performance on the two versions of the FEP test using Wilcoxon signed-rank tests (to contrast hFEP *vs* vFEP) and Mann–Whitney U tests (to contrast impaired *vs* unimpaired). To allow independent replications, we provide the full datasets and our analyses scripts for the healthy older participants and the people with brain damage at https://doi.org/10.17605/OSF.IO/RKYXN. No part of the study procedures or analyses was pre-registered prior to the research being conducted.

3. Results

3.1. *Pilot study: Healthy younger participants*

The performance of the group of younger participants demonstrated significant effects of AS and faster pace on the two different versions of the FEP. The vFEP proved better than the hFEP under AS [$t(62) = -6.92$, $p < .001$] and the faster pace [$t(62) = -11.82$, $p < .001$]. Interestingly, when asked during the debriefing session, younger participants commented that they found the hFEP more difficult than the vFEP five times more than the contrary.

3.2. *Main study: Healthy older participants*

The older group's mean accuracy in each of the four experimental conditions are reported in Table 1. In the normal condition, all older adults but one obtained an identical score for both the vFEP and hFEP conditions and no errors were made. The older adult who made an error scored higher on the vFEP than the hFEP.

A 2 (FEP: horizontal and vertical) × 4 (condition: normal, AS, HDAS, and fast paced) repeated measures ART ANOVA revealed a significant main effect of FEP [$F(1, 240) = 65.61$, $p < .0001$, $\eta_p^2 = .21$] where the vertical condition was performed more accurately than the horizontal condition. There was also a significant main effect of condition [$F(3, 240) = 39.80$, $p < .0001$, $\eta_p^2 = .33$] and post hoc Tukey tests revealed that the normal condition was performed more accurately than the AS, HDAS and fast paced conditions (*ps* < .0001) and the AS condition was performed more accurately than the HDAS condition ($p < .05$). Finally, the two-way interaction was also significant [$F(3, 240) = 68.38$, $p < .0001$, $\eta_p^2 = .09$]. Post hoc analysis using Tukey tests revealed that the AS, HDAS and fast paced conditions were performed significantly better in the vFEP conditions compared to the hFEP conditions (*ps* < .01).

Table 2 demonstrates the older adults' error types across the four conditions. When all the conditions were considered together, older participants rarely made a vertical fist orientation error (.1%) compared to 12.4% of the time when they oriented the horizontal fist incorrectly.

For the wrong fist orientation errors, the 2 × 4 repeated measures ART ANOVA with FEP type and condition as factors demonstrated a significant main effect of FEP type [$F(1, 240) = 15.28$, $p < .001$, $\eta_p^2 = .06$] where more wrong fists were

Table 1 – Mean accuracy out of 6 (standard deviations in brackets) for the healthy older group in the four experimental conditions.

	Normal	AS	HDAS	Fast paced
hFEP	5.97 (.18)	4.64 (1.33)	4.00 (1.65)	4.64 (1.20)
vFEP	6.00 (.00)	5.81 (.48)	5.32 (1.05)	5.45 (1.06)

hFEP = horizontal fist-edge-palm; vFEP = vertical fist-edge-palm; AS = articulatory suppression; HDAS = high demand articulatory suppression.

Table 2 – Mean number of errors (standard deviations in parentheses) of the older group by error type in the four experimental conditions.

	hFEP	vFEP
Wrong Fist Orientation		
Normal	.00 (.00)	.00 (.00)
AS	.77 (1.20)	.03 (.18)
HDAS	1.23 (1.33)	.00 (.00)
Fast paced	.97 (1.20)	.00 (.00)
Sequence Error		
Normal	.03 (.18)	.00 (.00)
AS	.58 (.78)	.16 (.45)
HDAS	.81 (1.14)	.68 (1.05)
Fast paced	.39 (.80)	.52 (1.00)

hFEP = horizontal fist-edge-palm; vFEP = vertical fist-edge-palm; AS = articulatory suppression; HDAS = high demand articulatory suppression.

Table 3 – Descriptive results for the performance of the patients on the neuropsychological background measures. Cut-off scores are derived from available norms. Best possible scores are reported.

	Mean	SD	Range	% Impaired	Cut-Off
IADL[a] (max = 8)	4.85	2.82	0–8	64.18	<8.00
Token Test[b] (max = 36)	28.19	6.24	1–36	25.37	<26.50
Cancellation Test[c] (max = 50)	27.52	10.67	9–50	46.97	≤30.00
CET[d] – Error score (max = 42)	18.87	3.84	9–29	66.13	≥18.00
Trail Making Part B[e] (seconds)	334.59	150.43	61–480	67.24	≥294.00
Prose Immediate Recall[f] (max = 8)	4.29	2.40	0–8	23.81	<3.10
Prose Delayed Recall[f] (max = 8)	3.07	2.71	0–7.9	41.27	<2.39
Digit Span[g] (max = 9)	4.73	.99	2–7	19.40	<4.26
Corsi Span[g] (max = 9)	4.08	1.01	2–6	13.64	<3.46
PRMQ[h] (error score, max = 80)	35.01	25.88	3–78	41.79	>45.00
LAB[i] Imitation Unknown Gestures (max = 16)	13.49	2.80	5–16	56.72	<15.00
Rey Figure Copy[j] (max = 36)	23.70	9.09	0–36	53.13	<28.88
Rey Figure Recall[j] (max = 36)	5.73	5.98	0–24	62.50	<9.47

IADL = Instrumental Activities of Daily Living; CET = Cognitive Estimation Test; PRMQ = Prospective and Retrospective Memory Questionnaire; LAB = Limb Apraxia Battery.

References:
[a] Wade & Hewer, 1987.
[b] De Renzi & Faglioni, 1978.
[c] Della Sala et al., 1992.
[d] Della Sala et al., 2003.
[e] Giovagnoli et al., 1996.
[f] Carlesimo et al., 2002.
[g] Monaco et al., 2013.
[h] Smith et al., 2000.
[i] Bartolo et al. 2008.
[j] Carlesimo et al., 1996.

produced in the horizontal condition than the vertical condition. The main effect of condition was also significant [F(3, 240) = 20.45, $p < .0001$, $\eta_p^2 = .20$] and post hoc Tukey tests found that more wrong fists were produced in the AS, HDAS and fast paced conditions compared to the normal condition (*ps* < .001) and in the HDAS condition compared to the AS condition ($p < .01$). Finally, the two-way interaction was also significant [F(3, 240) = 25.69, $p < .0001$, $\eta_p^2 = .24$]. Post hoc analysis using Tukey tests revealed that older participants produced the wrong first orientation significantly more in the AS, HDAS and fast paced conditions in the hFEP condition compared to the vFEP (*ps* < .0001).

Similarly for the sequence errors, there was a significant main effect of condition [F(3, 240) = 12.15, $p < .0001$, $\eta_p^2 = .13$] where more sequences were performed incorrectly in the AS, HDAS and fast paced conditions compared to the normal condition (*ps* < .01). The two-way interaction was also significant [F(3, 240) = 2.84, $p < .05$, $\eta_p^2 = .03$] but, this time, a significant difference between hFEP and vFEP was only found for the AS condition ($p < .05$). The main effect of FEP type was not significant ($p = .06$).

3.3. *People with brain damage*

Table 3 details the performance of the patients on the neuropsychological background measures. Table 4 presents the performance of the people with brain damage on the Frontal Assessment Battery (FAB) with the fist presented either vertically (vFEP), as in the traditional FAB, or horizontally (hFEP). Since the aim was to detect any difference in scoring between the two FEP orientations and given that controls' performance in the normal condition is at ceiling for both orientations (see Table 2), the norms used are those reported in the traditional FAB (Dubois et al., 2000). A Wilcoxon signed-rank test demonstrated that the patients scored significantly lower on the FAB when the fist was horizontal (median = 11) compared to vertical (median = 13) ($Z = 0$, $p < .0001$, $r = .86$). Thirty-seven patients were impaired on the horizontal version of the FAB compared to 24 patients on the vertical version.

In the patient group, age did not significantly correlate with any of the experimental FEP test measures (*ps* > .08). Education was only significantly related to the number of correct sequences on the hFEP and vFEP (*ps* < .005) where the higher the years of education, the higher the number of correct sequences. None of the other measures correlated with education (*ps* > .10). Mann–Whitney U tests demonstrated that there were no significant gender differences on any of the FEP test measures (*ps* > .30).

The patients' performance on the experimental FEP test is presented in Table 5. Wilcoxon signed-rank tests demonstrated

Table 4 – Descriptive results for the performance of the patients on the Frontal Assessment Battery with the fist oriented vertically (traditional FAB) and the fist oriented horizontally.

	Mean	SD	Range	% Impaired
FAB total overall score using horizontal fist (max = 18)	10.73	3.57	2–16	53.73
- standard FEP score using horizontal fist (0–3)	.76	.78	0–2	
FAB total overall score using vertical fist (max = 18)	12.01	3.84	2–18	35.82
- standard FEP score using vertical fist (0–3)	2.14	.95	0–3	

FAB = Frontal Assessment Battery; FEP = Fist-Edge-Palm test.

Table 5 – Mean performance (with standard deviations in parentheses; max = 6) achieved by people with brain damage on the FEP test.

	Horizontal	Vertical	*p* value	Effect size
Correct Sequences	1.48 (2.02)	3.69 (2.38)	<.0001	.76
Fist Correct Position	1.58 (1.99)	5.30 (1.40)	<.0001	.83
Wrong Fist Orientation Errors	3.63 (2.16)	.10 (.39)	<.0001	.85

that patients scored significantly lower and made more fist orientation errors on the FEP when their fist should be presented horizontally rather than vertically (*ps* < .001).

One possible account for these findings is that the position of the wrist when performing the fist is influenced by the position of the wrist when performing the subsequent edge. To investigate whether this is the case, we analysed the patients' individual sequences on the FEP test to examine whether the first sequence(s) would be better performed than the subsequent ones. Fig. 2 displays the mean errors for the six sequences examined separately for the hFEP and the vFEP. A 2 (FEP: horizontal and vertical) × 6 (sequence position: 1–6) repeated measures ART ANOVA demonstrated that the main effects of FEP type was significant [$F(1, 792) = 106.25$, $p < .0001$, $\eta_p^2 = .12$] where more errors were produced in the hFEP condition compared to the vFEP condition. The main effect of sequence position was also significant [$F(1, 792) = 6.75$, $p < .0001$, $\eta_p^2 = .04$]. Tukey post-hoc tests revealed that significantly fewer errors were made during the first sequence compared to the third, fourth, fifth and sixth sequences. However, there was not a significant two-way interaction [$F(5, 792) = .13$, $p = .99$, $\eta_p^2 = .001$]. Therefore, patients' performance on the FEP became poorer during the task when the fist was in both the horizontal and vertical positions.

Table 6 demonstrates the correlational analyses between performance on the background neuropsychological measures and the number of correct sequences on the FEP test. Performance on both versions of FEP was significantly related to all background measures except Corsi span and Digit span (in the case of the hFEP), and prose delayed recall and PRMQ (in the case of the vFEP).

Finally, Table 7 shows the performance of the cognitively impaired versus the cognitively unimpaired groups (as determined by the different neuropsychological tests) on the two versions of the FEP test. For the hFEP test, those individuals who were cognitively impaired on all the

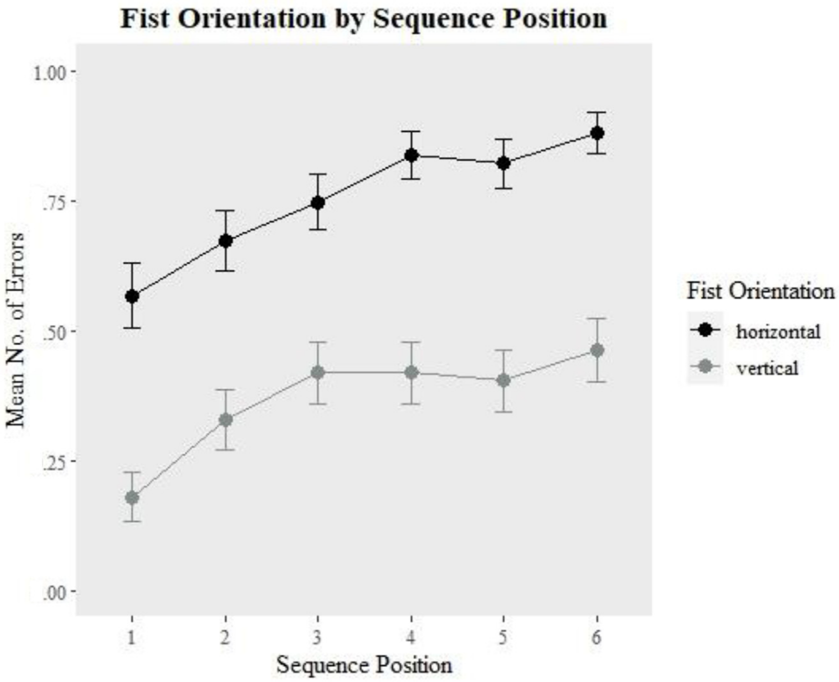

Fig. 2 – The mean number of sequence errors and standard error bars for each Fist-Edge-Palm type by sequence position.

Table 6 – Spearman correlations between patients' performance on background neuropsychological measures and FEP test correct sequences with horizontal and vertical fists. Spearman's rhos are reported for the associations.

	hFEP	vFEP
IADL	.41***	.32*
Token Test	.57*****	.46*****
CT	.45****	.41***
CET Error	−.42***	−.49*****
TMT Part B	−.66*****	−.55*****
Prose IR	.33*	.32*
Prose DR	.26*	.22
Digit Span	.09	.34**
Corsi Span	.20	.31*
PRMQ	−.35**	−.23
LAB	.59*****	.66*****
Rey Figure Copy	.47****	.42***
Rey Figure Recall	.42***	.32*

*p < .05; **p < .01; ***p < .005; ****p < .001; *****p < .0001.
hFEP = horizontal fist-edge-palm; vFEP = vertical fist-edge-palm; IADL = Instrumental Activities of Daily Living; CT = Cancellation Test; CET = Cognitive Estimation Test; TMT = Trail Making Test; IR = Immediate Recall; DR = Delayed Recall; PRMQ = Prospective and Retrospective Memory Questionnaire; LAB = Limb Apraxia Battery.

Table 7 – Mean correct sequences (standard deviations in parentheses) on the FEP test with horizontal and vertical fists for the patients categorised as impaired versus unimpaired on the background neuropsychological tests.

		hFEP	vFEP
IADL	Unimpaired	2.58 (2.15)***	5.67 (1.24)
	Impaired	1.02 (1.68)***	5.09 (1.46)
Token Test	Unimpaired	2.04 (2.10)*****	5.30 (1.40)
	Impaired	.24 (.56)*****	5.29 (1.45)
CT	Unimpaired	2.26 (2.11)***	5.46 (1.22)
	Impaired	.87 (1.61)***	5.10 (1.60)
CET Error	Unimpaired	3.26 (2.02)*	5.68 (1.16)***
	Impaired	1.05 (1.69)*	5.18 (1.45)***
TMT Part B	Unimpaired	2.67 (2.29)******	5.09 (.44)
	Impaired	1.22 (1.70)******	5.02 (1.59)
Prose IR	Unimpaired	1.85 (2.03)	5.27 (1.40)
	Impaired	1.13 (1.92)	5.33 (1.45)
Prose DR	Unimpaired	1.92 (1.98)	5.43 (1.37)
	Impaired	1.35 (2.06)	5.08 (1.44)
Digit Span	Unimpaired	1.54 (1.95)	5.31 (1.46)
	Impaired	1.77 (2.24)	5.23 (1.17)
Corsi Span	Unimpaired	1.72 (2.11)	5.46 (1.24)*
	Impaired	.78 (.83)	4.22 (1.99)*
PRMQ	Unimpaired	1.95 (2.08)*	5.41 (1.41)
	Impaired	1.07 (1.78)*	5.14 (1.41)
LAB	Unimpaired	2.69 (2.11)******	5.72 (1.00)**
	Impaired	.74 (1.43)******	4.97 (1.59)**
Rey Figure Copy	Unimpaired	2.37 (2.22)*	5.63 (1.03)*
	Impaired	1.00 (1.60)*	5.00 (1.60)*
Rey Figure Recall	Unimpaired	2.33 (2.01)*	5.42 (1.59)
	Impaired	1.23 (1.93)*	5.23 (1.27)

hFEP = horizontal fist-edge-palm; vFEP = vertical fist-edge-palm; IADL = Instrumental Activities of Daily Living; CT = Cancellation Test; CET = Cognitive Estimation Test; TMT = Trail Making Test; IR = Immediate Recall; DR = Delayed Recall; PRMQ = Prospective and Retrospective Memory Questionnaire; LAB = Limb Apraxia Battery.
*p < .05; **p < .01; ***p < .005; ****p < .001; *****p < .0005; ******p < .0001.

neuropsychological tests except prose immediate and delayed recall, Digit span and Corsi span performed significantly more poorly than individuals who were cognitively unimpaired. For the vFEP test, individuals who were impaired on the CET, Corsi span, Limb Apraxia Battery and Rey copy performed more poorly than individuals who were unimpaired. When performance on the hFEP and vFEP was compared separately for the spared groups and then the impaired groups, the hFEP test was always performed significantly more poorly than the vFEP test.

4. Discussion

4.1. *Effect of fist orientation in the FEP test*

The FEP test was introduced by Luria to assess the ability of people with brain damage to reproduce complex sequences of movements respecting precise hand figures and orientation. The test was proposed as a means of assessing motor coordination (i.e., kinetic organisation in Luria's terminology), and the ability to inhibit automatic motor responses (Henderson, 2010; Luria, 1966, p. 248). Luria showed that people with frontal damage were often impaired on this test, even if they were able to understand the instructions (see e.g., case 6 in Skolnik-Jarros (1966), p. 338). As it is the case for most neuropsychological tests, the FEP could be failed for several different reasons and its association with frontal damage is less cogent than initially thought. Moreover, not all dysexecutive patients have frontal lobe damage (for a discussion see Cubelli et al., 2023). However, the test has been widely used both in experimental and clinical settings.

The main aims of this study were to examine whether the orientation of the fist used in the administration of the FEP test produces different performance in healthy adults and whether one fist orientation is more sensitive to brain damage than the other. Both the findings from the healthy participants and the patient population show that the horizontal fist pose (hFEP), as originally devised by Luria (1966), and the vertical fist pose (vFEP), as used more recently (Dubois et al., 2000), are not equivalent, hence should not be used interchangeably. The hFEP proved more challenging both for healthy older adults and for people with brain damage. This finding was replicated in a group of younger participants.

Importantly, 13 additional people with brain damage failed the FAB and were considered impaired when the hFEP was administered compared to the vFEP (53.73% *vs* 35.82% respectively). These findings have clinical implications given this subgroup of patients were diagnosed as having impaired or intact performance according to the FAB depending on the fist orientation of the FEP. Therefore, if we aim to identify possible deficits in FEP performance, it would be better to adhere to Luria's original instructions.

The difference in cognitive demand between the two versions of the FEP allows us to revisit the relevant literature attempting to reconcile some of the conflicting findings and account for their contrasts. The performance of healthy older controls on the FEP seems to vary across studies using the same score (0–3). However, these studies did not use the same version of the FEP. Healthy older participants performed worse when assessed with the hFEP (mean = 2.1, SD = 1.0 – Canali et al., 2007) than with the vFEP (mean = 2.8, SD = .5 – Lima et al., 2008; mean = 2.9, SD = .3 – Terada et al., 2017). People with Mild Cognitive Impairment (MCI) performed normally on the vFEP (Fernández-Fleites et al., 2021; Goh et al., 2019) but pathologically on the hFEP (Economou et al., 2007; Weiner et al., 2011). Similarly, people with Parkinson's disease did not perform significantly worse than controls on the vFEP (Lima et al., 2008) but they did when assessed with a version of the hFEP (Kulisevsky et al., 2000). Finally, neuroimaging studies using fMRI showed that the hFEP (Umetsu et al., 2002) but not the vFEP (Chan et al., 2006) elicits additional premotor cortex activation compared to a baseline motor task. Therefore, in the light of the current findings, the data from the literature appear less contradictory than before, if one assumes that the hFEP is a more demanding version than the vFEP.

4.2. *Relationship between FEP and other cognitive tests*

Previous studies have shown that the FEP correlated with executive tests assessing inhibition, such as the Hayling Sentence Completion test, but not tests like the Stroop Colour-Word test (Varkovetski et al., 2020). In our data, both versions of the FEP were significantly negatively correlated with the Trail Making Test and the Cognitive Estimation Test, where the lower the FEP score, the slower the performance and the higher the error score respectively. However, performance on the FEP test was also correlated with tests of verbal comprehension, visual search, memory and apraxia. We are not maintaining that the FEP test does not tap executive functions nor that it does not have clinical utility but rather than being a specific test of executive dysfunction, performance on the FEP test most likely depends upon a range of cognitive processes, so failure can occur for several reasons. Indeed, as our patient sample included patients who had no difficulty performing the FEP test as well as patients who performed at floor, we also examined whether the impaired and unimpaired groups were differentially affected by the FEP version. Here, the hFEP test was performed significantly more poorly by those with impairments on most of our neuropsychological battery except prose memory, Digit span and Corsi span compared to those who were not impaired. In contrast, for the vFEP test, fewer neuropsychological tests differentiated between those who were cognitively impaired compared to those who were not cognitively impaired (i.e., CET, Corsi span, Rey Figure copy and the Limb Apraxia Battery). However, when contrasting the spared versus impaired groups' performance on the hFEP and vFEP tests, both cognitively intact and cognitively impaired individuals performed better on the vFEP test compared to the hFEP test. These results suggest that the FEP test may have limited use as a tool in specifically identifying frontal executive dysfunction and instead might better indicate brain impairment more generally, particularly when the hFEP test is administered. This is an issue for several test assessing executive functions, which are unable to capture the behavioural problems that these patients (and their carers) face in their everyday life (for discussion see MacPherson & Della Sala, 2015). Unfortunately, our patient group did not allow us to examine localization of vFEP or hFEP performance and so future work might examine whether performance on either version of the FEP test can distinguish between frontal and non-frontal lesions.

4.3. *Effect of demographics, articulatory suppression and pace on FEP*

Analysis of our data on brain damaged people revealed that performance on the FEP test was not related to age or gender. However, lower levels of education were related to fewer correct sequences on both the hFEP and vFEP. These findings are in line with the previous results of Nitrini et al. (2005) who demonstrated that age and gender were not associated with poor performance on the FEP test in a large group of healthy older adults (n = 966). On the other hand, lower levels of education were related with impaired performance on the FEP test.

Our healthy older group also performed the FEP test under different conditions. While the AS, HDAS and fast paced conditions were performed significantly more poorly than the normal condition for both the hFEP and vFEP, all three experimental conditions were performed more poorly when the fist was oriented horizontally. The two FEP versions did not significantly differ under normal conditions. The disruption in FEP performance using concurrent subvocal articulation suggests that older adults might use verbal strategies to reproduce the FEP motor sequences, as originally suggested by Luria (see Skolnik-Jarros (1966)), especially when the test is administered according to Luria's original instructions. This replicates previous findings with similar hand movement sequences (Frencham et al., 2003; Mitsuhashi et al., 2018), which have been interpreted as the effect of inhibiting possible verbal labelling to ease the recall of the series of movements. However, given that subvocal articulation affects both the hFEP and vFEP, it cannot be solely responsible for the difference between the two versions of the task. Moreover, even counting backwards from 101 requires some cognitive control, hence the observed effects could be due to a combination of articulatory suppression and dual-tasking.

Speed of presentation (and execution) also modulated the performance on the FEP test in our older adults. Varkovetski et al. (2020) reported no significant difference in healthy people performing the FEP at 60 bpm or 120 bpm. However, Kobayashi et al. (2021) suggested that speed of presentation has an effect at 180 bpm, which is the speed used in the current study. The processing speed theory proposes that age-related cognitive decline in performance is associated with a general reduction in information-processing speed (Salthouse, 1996). Age-related differences on cognitive tests are due to declines in the rate that the fronto-executive system can perform simple operations. Processing speed has been found to influence performance on tests of fluid intelligence (Salthouse et al., 1998), reading and computation span (Salthouse & Babcock, 1991), working memory (Salthouse, 1992), recall, reasoning, and spatial abilities (Salthouse, 1993) and executive tests (Salthouse, 2005, 2011), although it does not entirely explain the age effects found (Argiris et al., 2020; Keys & White, 2000). Therefore, it is not surprising that increasing the speed of presentation on the FEP test negatively impacts performance. Yet, as was the case for the articulatory suppression conditions, speed of presentation affected performance on both versions of the FEP, and so cannot account fully for the differences in performance between the hFEP and vFEP.

The orientation of the fist in the vFEP version is the same orientation as the edge that comes next in the sequence whereas, in the hFEP version, there is an extra rotation required. Since people are performing a continuous series of hand positions, this relationship could matter, particularly as the movements become more automatized with practice. To examine whether this might account for the difference between the two versions of the FEP, we compared the performance of the patients on the first trial versus the other trials. There is a clear indication that performance worsens with the increasing number of trials. However, the lack of an interaction between trials and fist orientation suggests that the difference between the hFEP and vFEP cannot be traced back to the extra rotation of the wrist required to progress from the horizontal fist to the edge hand position.

The difference between the hFEP and vFEP could be traced back simply to the fact that it is more “natural”, hence automatic, to position a fist vertically rather than horizontally. This is reflected in the participants' impression of the test. When asked which of the orientations were more “difficult”, participants overwhelmingly commented that the hFEP was more difficult than the vFEP.

4.4. *Other neuropsychological tests undermined by subtle changes in their administration*

The effect of the different orientation of the fist between the original Luria's fist-palm-edge test and subsequent versions, like that used in the FAB (Dubois et al., 2000), shows that apparently innocuous variations in task instructions may change the outcome of a neuropsychological test. The problem with different outcomes resulting from slight modifications in the instructions given to participants or strategies used to comply with the test requirements is not new. Robinson (2001, cited by Cowan & Rachev, 2018) reports that Wilhem Wundt observed that participants were faster in a reaction time experiment when focussing on their own responding hand rather than when asked to focus on the bell.

The FAB offers other examples of different outcomes from modified instructions. The FAB has been translated in several languages (Appollonio et al., 2005; Moreira et al., 2017), but some of these translations have distorted the meaning of the original question. In the item presenting two fruits, when the translation asks, “How are they similar?”, the response focuses on perceptual features like, “the texture of their skin is the same”, resulting in an error. On the other hand, the answer is more often categorical (i.e., correct), for example, “They are both fruit”, when the original question is rendered as, “What do they have in common?”

Other tests proposed for the assessment of executive functions, like the Trail Making Test (TMT), have also resulted in different outcomes when the test administration procedures are varied. Stuss et al. (2001) found specific deficits in people with frontal lesions performing the TMT, whereas Chan et al. (2015) did not. However, the participants in Stuss et al.'s study were asked to perform both parts of the TMT (A and B). In contrast, the participants in Chan et al. (2015) were only tested on part B. It could be that the training offered by performing part A prior to part B results in differences in performance between the groups (i.e., participants learn to connect consecutive numbers and so are more impaired when they are then asked to switch between numbers and letters).

Similarly, to assess the production of pantomime to detect praxis deficits, usually objects are presented visually or by verbal command (Bartolo et al., 2003). Verbal instructions are given either by providing the name of the object (e.g., “Show me how to use a pen”) or by requiring the object function (e.g., “Show me how to write”). These modes of testing are used interchangeably. However, results have shown that pantomime by function produces poorer performance than naming the object to mime (Bartolo et al., 2020). Results differ according to the position of the target in assessing constructive apraxia by copying geometrical drawings (Ambron & Della Sala, 2017). Similarly, the amount of retained material after a delay differs in prose memory tasks according to the type of activities performed during the delay (Cowan et al., 2004).

Precise instructions are paramount. MacPherson (2001) failed to replicate the original findings on the Iowa Gambling Task reported by Bechara et al. (1994); contrary to the original study, the healthy participants in her experiment preferred the decks offering less frequent punishments rather than the decks offering long-term profits. This difference was simply due to a slight modification in the instructions. In the Bechara et al. studies (Bechara et al., 1994, 1999), participants were told that some decks were worse than others. In the MacPherson study (2001), participants were not given such information, so they did not realize that the decks were different. In another example where Cocchini et al. (2001) used the Fluff Test to diagnose personal neglect, participants were asked to pick targets attached to their limbs with Velcro®. The instructions stress that the experimenter should ask the participants to find the targets “all over your body”, but when this instruction is omitted (an apparently minor aspect of the instructions), healthy participants miss a few items.

Even variability in voice inflection or emphasis can modify the outcome to a neuropsychological test. A curious instance comes from the amusing anecdote about the improvement shown by aphasic patients on the Token Test (De Renzi & Vignolo, 1962) when tested by a clinician blessed with a histrionic and gestural Southern Italian vernacular compared to the monotonic and restrained Northern Italian language (Trojano et al., 2021). Likewise, when administering Digit Span, the results can change according to the pace of presentation, variation in voice pitch when presenting different items, or the number of sequences presented (Raiford et al., 2010, pp. 34–35) as well as allowing participants to use different strategies to complete the task (Logie et al., 1996). The same applies to dual-task performance. Belletier et al. (2022) showed that participants strategically adapted to the requirements of a test and argued that we should not assume that participants perform the same task in the same way.

In some instances, several versions of the same task exist. For example, a test typically used to assess executive functions, the Tower test, refers to a family of tests that differ from one another. They include the Tower of London (Shallice, 1982) and its several variations (e.g., Allamanno et al., 1987), including the Tower of Hanoi (Byrnes & Spitz, 1977), the Stockings of Cambridge (Robbins et al., 1994), and the Tower subtest from the Delis–Kaplin Executive Function System (Delis et al., 2001). They all differ from one another in terms of stimuli, rules and/or scoring system. Each of these small disparities in administration or scoring might result in differences in performance or in neuroanatomical correlates (Gilhooly et al., 2002; Phillips et al., 1999).

5. Conclusions

Nuances of test instructions may be misleading. Clinicians and researchers alike should be aware of this possible bias, as a poorer or better performance may not reflect the presence or absence of a deficit, but rather be due to slight differences in the test administration procedures or in the wording of the instructions. This is particularly relevant in the case of tests derived from older literature, such as the FEP, where the instructions for which may not be as exact as one wishes (see Murre & Dros, 2015).

Open practices

The study in this article earned Open Data and Open Materials badge for transparent practices. The data and materials used in this study are available at: https://doi.org/10.17605/OSF.IO/RKYXN.

Conflict of Interest

The authors have no conflicts of interest to daclare.

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