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Coding Movement in Sign Languages: the Typannot Approach

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ABSTRACT

Typannot is an innovative transcription system (TranSys) for Sign Languages (SLs), based on robust graphematic and coherent typographic formulas. It is characterized by readability, writability, searchability, genericity and modularity. Typannot can be used to record handshapes, mouth actions, facial expressions, initial locations (LOCini) and movements of the upper limbs (MOV). For LOCini and MOV, Typannot uses intrinsic frames of reference (iFoR) to describe the position of each segment (arm, forearm, hand) in terms of degrees of freedom (DoF). It assumes that the motion is subdivided into a complex moment of initial preparation, leading to the stabilization of a LOCini, and a subsequent phase of MOV deployment based on simple motor patterns. The goal of Typannot is not only to create a new TranSys, but also to provide an instrument to advance the knowledge about SLs. The observation of the SLs makes it possible to formulate various hypotheses, among which: 1) MOV follows a simple motor scheme that aims at minimizing motor control during MOV; 2)

proximal→distal flows of MOV are predominant in SLs. Only the use of a TranSys based on iFoR and the description of the DoF makes it possible to explore the data in order to test these hypotheses.

CCS CONCEPTS

• Human-centered computing-Interaction design • *Human-centered computing-Gestural input* • Human-centered computing-Accessibility • Social and professional topics-People with disabilities

KEYWORDS

Sign Language, Transcription System, Handshape; Movement, Initial Localization, Intrinsic Frame of Reference, Motion Capture, User Interface.

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1 INTRODUCTION

The analysis of any language requires the implementation of a system of graphical representation to set the characteristics that make them analyzable and comparable. Linguistics started its development through written materials [1, 2], and only in the last few decades it has been involved with spoken languages. The development of new multimedia technologies has not changed the situation: even if we can record sound and gestures associated with any language without problems, organizing and storing data on the basis of the elements deemed relevant requires a transcription system (TranSys) to pass from a simple collection to a usable corpus of data: i.e., to record is not to categorize.

To make possible accurate analyses and their reading, a TranSys must meet 5 main criteria [3]: readability, writability, searchability, genericity and modularity. A TranSys must be able to be written and read by human transcribers but also by the machines that manage the information (readability and writability). On one hand, the system shall allow a detailed and structured representation of languages using a systematic graphematic formula (genericity) and, on the other hand, it shall propose an integration of these minimal components within larger formal structures, allowing synthetic representations (modularity). The data thus transcribed should allow computer queries for fine and distinct characteristics (searchability) while displaying different levels of visual synthesis in order to facilitate their understanding (readability).

For the vocal languages (VLs), these criteria are satisfied by more or less detailed adaptations of existing writing systems, in particular by the Latin alphabet [4] and by its derivation, the International Phonetic Alphabet (IPA) [5]. But what about Sign Languages (SLs)?

SLs are languages used by most deaf¹ people to communicate within their community. SLs are produced through the simultaneous movement of several articulators located on the upper limbs (hands, forearms and arms) and the face (eyes and mouth, mainly) of the signer.

Despite various attempts over the centuries [6, 7], SLs have not yet developed a notation system of their own, so there is a lack of a graphic base that can be adapted to create a TranSys. The absence of a TranSys was felt as a problem since the early researches on SLs done by Stokoe [8], who for this reason invented a rudimentary TranSys focused on the shapes and movements of the hands, known as the "Stokoe notation".

Given the difficulty of taking into account the formal characteristics of SLs, some researchers have opted for TransSys that encode only the signified of VLs (for example Id-Gloss [9]). In contrast, a small number of researchers tried in the '80s to find solutions to this problem, generating various systems, e.g. Signfont [10], D'Sign [11], SignWriting (SW) [12, 13], Hamburg Notation System (HamNoSys) [14]: today, only the last two are

still in use, SW being aimed more to deaf people and educators, HamNoSys to linguists.

SW (Figure 1) is a system based on a set of characters detailing all the components of SLs (manual and non-manual). The characters are arranged in a two-dimensional space that analogically represents the signing space. SW is easily readable by humans, but this does not go together with its very laborious writability, by both hand and computer. Moreover, born outside of the concerns of the world of linguistic research, SW is not easy to search. Finally, its characters are a global representation of a sign parameter, and therefore they are neither generic nor modular.

HamNoSys (Figure 1) is a more modern and detailed version of the Stokoe Notation. It is a linear graphic system that accurately represents the manual components of the SLs. It has been conceived to promote computer writability and searchability, perhaps to the detriment of human readability. The system is partially modular but not generic.

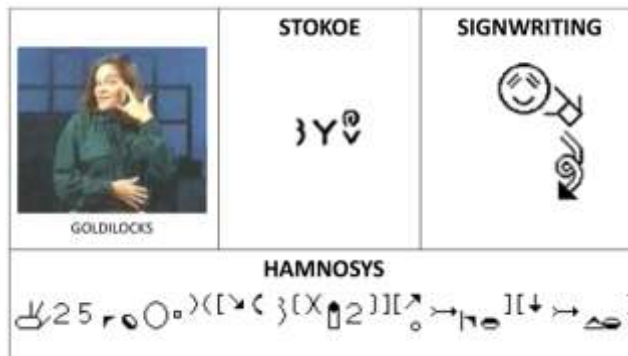


Figure 1: [GOLDILOCKS] in American Sign Language, written with three different transcription systems. Source: www.signwriting.org

Since 2013, a third TranSys of SLs is emerging: it is Typannot [15], realized within the l'École supérieure d'art et design (ESAD, Advanced School for Art and Design) of Amiens (France) by the GestualScript team, a multidisciplinary group of linguists, graphic designers, calligraphers, designers and computer scientists.

This article starts with the description of the HandShapes (HS) parameter to explain the concept of Typannot and its user interface (UI), followed by a presentation of initial localization (LOCini) and movement (MOV) parameters, which obey multiple (one per segment of the upper limb), intrinsic Frames of Reference (iFoR) according to Levinson [16], allowing to understand the relationship between the position of the limb articulators and the movement. Finally, the article shows how data transcribed using Typannot and its iFoR make it possible to give an answer to these two questions:

- how is it possible that MOV in SLs is standardized and simple, while its very principle brings it to continual changes?
- how may we determine MOV from its preparation phase?

¹We decided to use the term "deaf" because of a cultural issue: even if, for hearing people, this term might seem "politically incorrect", most deaf people, especially those who use SLs, do prefer to be called "deaf" (that underlines a difference) than "hearing impaired" (that underlines a handicap).

2 PRESENTATION OF TYPANNOT

Typannot is a typographic system that offers a description of the SLs forms using both symbolic and explicit visual analogies, thus enabling the advancement of linguistic knowledge [3]. It allows coding different parameters, both manual (HS, LOCini and MOV) and non-manual (mouth action and eye expressions). It is designed to meet the 5 criteria of a TranSys: readability, writability, searchability, genericity and modularity.

The analysis of the HS parameter allows understanding the general framework of the approach, since for all the other components the creation process follows the same steps and generates the same levels of representation (Figure 2). The issue for us is not to animate an avatar, but rather to transcribe SLs corpora. Therefore, the synchronization between several parameters is not a sought-after outcome, being each one sufficient separately.

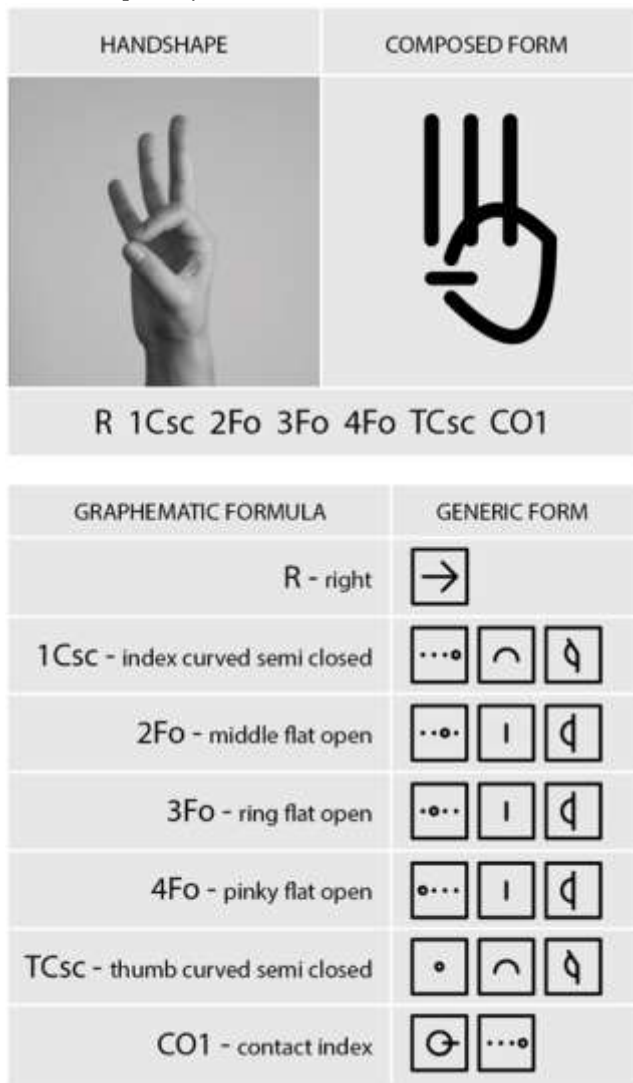


Figure 2: The three levels of representation of Typannot: example of a HandShape

2.1 Typannot levels of representation: the HandShape example

2.1.1 *Graphematic formula* . In the first place, it has been necessary to establish a graphematic formula [17], i.e. an ordered list of features relevant for the description (Figure 2).

The HS parameter is the most studied by the SLs linguists [8, 18, 19, 20]. After evaluating various studies on this subject, it has been chosen to refer to the phonological study of 9 SLs by Eccarius and Brentari [21], which seems to be quite complete to serve as a descriptive basis for all the HS of the 142 SLs of the world [22]. For HS, the graphematic formula is composed by 22 features (Figure 3).

It was not the same for the other parameters, where the GestualScript team had to establish the list of the relevant traits by itself.

2.1.2 *Generic characters* . On a second step, the 22 features of the graphematic formula are translated into 22 generic characters (Figure 3), that are written in a linear way following strict syntactic rules (Figure 2).

In order to ensure data queries with every operating system and software, the GestualScript team aims to have Typannot recognized by the Unicode Consortium. The set of possible HS being of several millions (although those actually recorded in 9 SL [21] do not exceed half a thousand), only the 22 generic characters will be registered in Unicode.

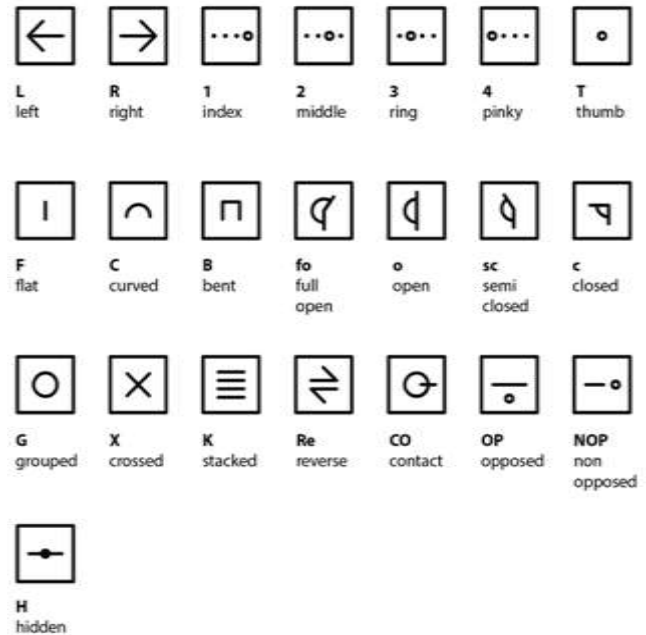


Figure 3: Typannot primary generics characters for HandShapes.

2.1.3 *Composed forms* . Although using just generic characters is sufficient to identify a HS, Typannot allows a composed typographic form for each HS generic transcription. This final level of representation aims at providing a better readability and writability. It integrates a set of typographic components into a

single unit (oppose to the linear vector of the generic forms) to build a logographic form. Similarly to the generic characters, composed forms are displayed automatically using the OpenType ligature functionality, replacing an entire line of generic characters by a single composed form (Figure 2).

Thus, like in the Latin alphabet "a+e→æ", typing several generic characters may create alternative level of representations (composed forms) that are back-decomposable (and therefore searchable).

For the HS, the three levels of representation have been fully realized. A font allowing to visualize both generic and composed characters of each HS is at advanced stage. Moreover, Typannot allows to represent mouth actions, eye expressions and LOCini: for these components, development reached the second level. Conversely, MOV representation is still at the early level, i.e. the availability of a sketch of the graphematic formulas without its development into character sets.

2.2 Typannot User Interface (UI)

To enable the use of Typannot in every platform and software, a UI is under development, allowing to write it according to different modalities, according to the users' requirements and skills, thanks to the presence of three complementary sub-interfaces (sUI):

- generic sUI (selection of generic characters);
- module sUI (selection of "morphological" modules of the specific typographic formula);
- gestural sUI (selection through the physical reproduction of the component to be described, thanks to the use of capture devices, i.e. LeapMotion for HS [Figure 4] and Inertial Measurement Unit [IMU] for LOCini).

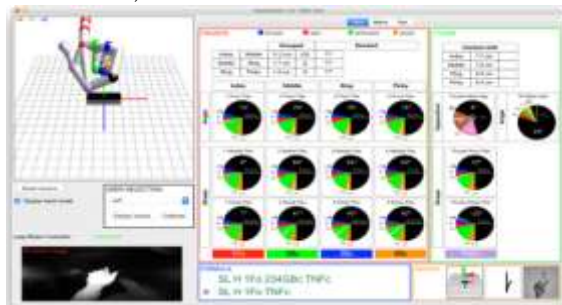


Figure 4: Typannot User Interface: gestural sub-interface for handshapes (back-end version).

It is possible to switch from one sUI to another to refine or correct the description, and a signing avatar should allow, at any time, to verify the accuracy of the transcript.

Whatever the sUI used, the UI restores both the generic formula and the specific "morphological" character. Using the Typannot font allows viewing the result in all OpenType supporting programs.

Along with the HS, Typannot proposes a new system to transcribe three interdependent parameters: the position and the

orientation of the hand, and the posture of the arm. These data are translated through a single notion, i.e. LOCini, a principle to characterize MOV in a novel way.

3 INITIAL LOCALIZATION (LOCini) AND MOVEMENT (MOV)

The movements of the upper limbs (MOV) are the result of a concatenation of actions of different articulators that act simultaneously: for this reason, MOV is considered the most difficult parameter to describe and, therefore, to represent [23].

In order to successfully overcome the drawbacks of MOV representation, most SLs TranSys focus on describing the trajectory of the hands, annotating trajectory and/or position of the other segments only if it cannot be easily deduced by the information about the hand itself [24, 25]. Conversely, the GestualScript team starts on a completely different basis.

The LOCini is classically seen according to an extrinsic, egocentric Frame of Reference (eFoR) in which only the position of the hand is considered, according to a frame centered on the speaker (front, back, left, right, top and bottom).

The approach chosen by GestualScript considers that LOCini and MOV are both accountable for the relative positions and movements of each segment (SEG: hand, forearm and arm) and therefore novel iFoR, intrinsic to each SEG and multiplied by all the SEGs, shall constitute the structuring level of the signs [26].

3.1 Novel approach for the movement (MOV)

3.1.1 Degrees of Freedom (DoF) and intrinsic Frames of Reference (iFoR).

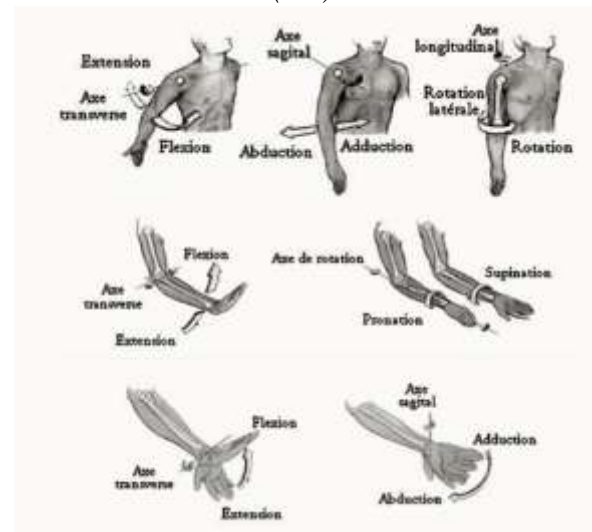


Figure 5: The degrees of freedom (DoF) of the upper limbs.

Typannot therefore proposes a novel approach based on taking into account the three SEGs of the upper limbs: arm, forearm and hand. For each of them, the different Degrees of Freedom (DoF) [27] (Figure 5) are underlined, together with their grades, going from one pole extremity to the other:

- arm: flexion/extension (with grades Flex2, Flex1, Flex0, Ext1, Ext2); abduction/adduction (Abd1, Abd2, Abd0, Add1, Add2); internal/external rotation (RInt2, RInt1, RInt0, RExt1, RExt2);
- forearm: flexion/extension (Flex2, Flex1, Flex0, Ext1, Ext2); pronation/supination (Pron2, Pron1, Pron0, Supi1, Supi2);
- hand: flexion/extension (Flex2, Flex1, Flex0, Ext1, Ext2); abduction/adduction (Abd1, Abd0, Add1, with just 3 grades).

To allow the description of DoF, the usual eFoR is not suitable. Therefore, Typannot is based on an iFoR for each SEG:

- the shoulder iFoR allows describing MOV and LOCini of the arm;
- the arm iFoR allows describing those of the forearm;
- the forearm iFoR allows describing those of the hand.

The three iFoR make it possible to precisely locate the position of all the SEGs participating in the MOV. If at first this approach seems more complicated than the eFoR, the iFoR allow many savings on the transcription of the MOV, as shown below.

3.1.2 *Initial Location (LOCini)*. The second basic premise of Typannot for MOV is that the LOCini, i.e. the stable position assumed by the SEGs of the signer's upper limb(s) before the deployment of MOV, is the key towards a simple description of MOV itself.

In SLs, MOV is a nearly continuous and complex flow that oscillates between a preparation moment (which culminates in a LOCini) and a deployment phase (that is, the MOV itself). However, these displacements are not the result of chance and one can find simple and standardized patterns. This paradox leads to two questions:

- how can MOV be standardized and simple, as it changes continuously?
- can we, and how, predict MOV from the observation of LOCini?


Before MOV takes place, the signer stops his/her action for a while: he/she blocks the LOCini, and his/her limbs are positioned to allow deploying MOV whilst minimizing the motor control. It is therefore possible to say that the preparatory phase for LOCini also consists in setting up the SEGs in a balanced and sufficiently stable LOCini to serve as anchor point and as basis for a simple MOV flow (from the point of view of the motion scheme). In other words, in order to reach the LOCini, the signer performs a series of potentially complex actions implementing each SEG, so that the sign MOV can be deployed through a simple motor scheme. One of the issues with motor schemes, especially with a large gestural lexicon, is avoiding to imply a massive storage of schemes, all specific [28]. Naturally, the conception of the motor scheme takes into account the motions laws, like the Fitts law [29], the 2/3 power law [30] and the diadochal movements [31].


3.1.3 *Movement (MOV)*. The representation of LOCini renders superfluous the description of the preparation phase, thus strongly reducing the elements to be described in MOV. After registering the LOCini, it is sufficient to consider the DoF on which MOV has repercussions and the type of impulse.

Although it often seems visually that several SEGs are in action, it is possible to deduce which is the SEG that "carries" the MOV impulse and how MOV propagates.

An example allows to better understand these last affirmations. The two signs on Table 1 means [THANK YOU] in French SL (LSF).

Table 1: Two signs to say [THANK YOU] in French Sign Language with transcription of initial location (LOCini), movement (MOV) and impulse (differences shown in bold).

			
LOCini	Arm: Add0 Flex0	Forearm: Flex2 RInt2	Hand: Supi1 Flex0 Add1
MOV	Segment affected: Forearm to hand		Pulse: Arm RExt ForearmExt

			
LOCini	Arm: Add0 Flex0	Forearm: Flex2 RInt0	Hand: Supi1 Flex1 Add1
MOV	Segment affected: Arm		Pulse: Arm Ext

However, looking at their transcript it is possible to note that: their LOCini differs slightly in terms of grades and not in terms of poles (-2 grades for the forearm, which remains in RInt, and +1 grade for the hand which stays in Flex); the SEGs affected by MOV are not the same, and if the pulses are different, they affect in any case two aligned poles, i.e. the extension of the arm and the extension of the forearm.

They are thus two realizations of the same sign, which go visually in different directions but which are physiologically quite similar: the difference of LOCini being only a question of grades. Only an approach based on iFoR and a description of the SEGs makes it possible to note this difference: the egocentric observation of the only trajectory of the hand would probably not have made it possible to reconcile these two realizations of which one sees a MOV directed inward and downward, while for the other MOV is directed forward and downward. The analysis in terms of separate DoFs we develop here is not the only one we would like to investigate: vectors of quaternions (angles) or vectors of positions are some other potential solutions.

3.2 How Typannot generates new knowledge

As stated in the presentation of Typannot (§2), the goal of the GestualScript team is not only to create a TranSys, but also to

provide an instrument capable of advancing knowledge on SLs and gestures: the following section shows how Typannot makes it possible to investigate SLs.

3.2.1 Hypotheses . The first assumption looks at the complexity of the motor control. By observing the sign [NEVER]² in LSF, we see that it can be done with the palm in a horizontal plane and downwards or in a vertical plane, but in both cases MOV will be a simple abduction of the hand. The motion scheme is simple and identical for this sign, regardless of the achievements. This example, and many others, allows us to formulate a first hypothesis:

- Hypothesis A: MOV has a simple motor scheme aimed at minimizing motor control during MOV.

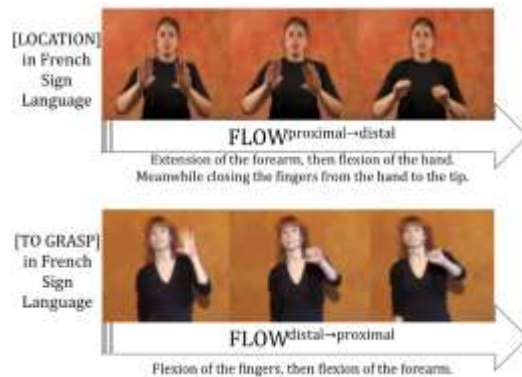


Figure 6: The flows in French Sign Language signs [LOCATION] and [TO GRASP].

The second supposition concerns the MOV propagation flow (FLOW) along the upper limb. If we compare the signs [LOCATION] and [TO GRASP] in LSF (Figure 6), we notice that MOV follows a proximal-distal flow (hand→fingers, $FLOW^{Prox \rightarrow Dist}$) in the first case, and a distal-proximal flow (hand→arm; $FLOW^{Dist \rightarrow Prox}$) in the second case. The $FLOW^{Prox \rightarrow Dist}$ only affects the hand and the fingers, and only appears in the few realizations showing a change of HS during signing. Generally, the great fixity of the HS during signing seems to show that the flow is mainly a $FLOW^{Dist \rightarrow Prox}$. However, working on MOV in general (and not on the SLs), Dumas [32] states that the inertia of the hand compared to the forearm is only 24% and that of the forearm to the arm is 65%: there is an inertial tendency towards a $FLOW^{Prox \rightarrow Dist}$ which should also affect the fingers (change of HS). The difference between what Dumas asserts and the observations on HS changes leads to a second hypothesis:

- Hypothesis B: the inertial tendency towards a $FLOW^{Prox \rightarrow Dist}$ of MOV is predominant also in SLs.

3.2.2 Materials and methods . To test these hypotheses, Typannot was used to transcribe three short extracts (about 1

min each) of narrations, each told in a different SL³. These are "L'histoire du cheval" [33] in French SL (LSF) (duration: 60 sec), "Pinocchio in LIS" [34] (duration: 113 sec) in Italian SL (LIS) and "Holiday in Lanzarote (BF21n)" [35] (duration: 50 sec) in English SL (BSL).

The extracts have been transcribed with the ELAN software [36], using the Typannot generic characters to encode MOV.

It must be remembered that only the graphematic formula has been developed for LOCini and MOV (see §1) and that the UI is still under realization. The transcription work could therefore only be based on the graphical aspect of Typannot: in fact, the corpus has been annotated with an alphanumeric keyboard, without resorting to the generic and composed characters and without recourse to the UI. In these conditions, the transcription of a single minute may require up to 5 hours of annotation (ratio: 1/300), which more or less corresponds to the time required using other TranSys [37]. This length depends not only on the complexity of the parameters but also on the ergonomics of the tools used, both in terms of graphic signs and input interfaces.

A collateral hypothesis emerges from these considerations:

- Collateral hypothesis: using iFoR common to the IMU MoCap device and to Typannot, together with a suitable interface (such as the Typannot UI), drastically reduces MOV transcription times.

3.2.3 Tests and preliminary results . In the corpus, 333 MOVs have been counted: 92 in LSF, 153 in LIS and 88 in BSL. These MOVs were then categorized differently to test the hypotheses: Test 1 pertains to Hypothesis A, Test 2 to Hypothesis A and the Collateral hypothesis, and Test 3 to Hypothesis B.

Test 1₁ MOVs were ranked on the basis of the number of MOV-deploying SEGs and within each SEG the number of DoF at the MOV origin, if this is the case (Table 2).

The predominance of MOVs concerning only one DoF (initiator of the rest of the MOV) on a single SEG is highly significant ($p < 0.001$): whatever the SLs considered, nearly 80% of MOVs are directed by a single DoF and the other SEGs reposition accordingly with the MOV-initiating DoF.

Table 2: Distribution of movement complexity.

	⊖ ←----- Movement complexity -----→ ⊕								Proba- bility
	∅ SEG	1 SEG	1 SEG	2+ SEG	∅ DoF	1 DoF	2+ DoF	2+ DoF	
		%	%	%	%	%	%	%	
LSF	7	7.6%	72	78.3%	5	5.4%	8	8.7%	10^{-7}
LIS	15	9.8%	119	77.8%	11	7.2%	8	5.2%	10^{-12}
BSL	9	10.2%	70	79.5%	2	2.3%	7	6.9%	10^{-8}
TOT	31	9.3%	261	78.4%	18	5.4%	23	6.9%	10^{-26}

³ These three extract were transcribed by one single person, thus making consistent the comparisons presented in the following tables; still, for more stringent analyses, it is envisaged to have more people interacting and cooperating, with the aim of standardizing the transcriptions.

² [NEVER] in LSF, with vertical palm: see Elix-LSF.fr <https://goo.gl/aPGC7u>
[NEVER] in LSF, with horizontal palm: see Sematos.eu <https://goo.gl/svStQH>

Therefore, the preliminary results seem to validate Hypothesis A: despite the apparent complexity of MOVs, these are, for the most part, governed by a simple motor scheme.

Test 2. MOVs were also classified on their potentiality for being tracked by a MoCap system, i.e. MOVs being initiated by a single DoF and those whose form matches an algorithm like the circle; Table 3 reports these numbers and their sum.

Table 3: Frequency of trackable movements (MOV).

	1 SEG 1 DoF		Circles		Trackable MOV		Non-trackable MOV	
		%		%		%		%
LSF	72	78.3%	11	12.0%	83	90.2%	9	9.8%
LIS	119	77.8%	27	17.6%	146	95.4%	7	4.6%
BSL	70	79.5%	14	15.9%	84	95.5%	4	4.5%
TOT	261	78.4%	52	15.6%	313	94.0%	20	6.0%

It appears that for more than 90% of the signs it is possible to determine the MOV origin, irrespective of MOV performed.

These data make it possible to show the interest of a UI integrating a system of IMU-like MoCap. This is based on an iFoR system, so the relative data that such equipment provides are easily convertible into Typannot categorical data, based on an iFoR system too. If the IMU and the development implemented in the UI allow to recognize 90% of MOVs, it will be sufficient for the transcriber to redo the movements that he/she visualizes in the video to automatically transcribe them in Typannot, thus minimizing the transcription duration.

Test 3. MOVs were classified based on their flow direction ($FLOW^{Prox \rightarrow Dist}$ or $FLOW^{Dist \rightarrow Prox}$) (Table 4).

Table 4: Distribution of flow.

	$FLOW^{Dist \rightarrow Prox}$		$FLOW^{Prox \rightarrow Dist}$		Static	Un-define d	1 DoF		Proba- bility	
		%		%				%		
LSF	54	58.7%	8	8.7%	7	7.6%	0	0.0%	2 25.0 3 %	0.117 4
LIS	98	64.1%	15	9.8%	1	9.8%	2	1.3%	2 15.0 3 %	0.000 6
BSL	61	69.3%	0	0.0%	9	10.2%	2	2.3%	1 18.2 6 %	0.000 4
TOT	213	63.7%	23	6.9%	3	9.3%	4	1.2%	6 18.6 2 %	10^{-8}

Results are less marked here, but it appears that $FLOW^{Dist \rightarrow Prox}$ is dominant in more than 60% of MOVs ($p < 0.001$), while the remaining 40% is subdivided between $FLOW^{Prox \rightarrow Dist}$ (less than 10%), absence of a well-defined flow, MOV on a single DoF (without transfer to another SEG), and total absence of MOV (static).

These preliminary results do not corroborate Hypothesis B: in spite of the inertial tendency towards a $FLOW^{Prox \rightarrow Dist}$ established by Dumas [32] for the movements in general, it is the

$FLOW^{Dist \rightarrow Prox}$ to be predominant in SLs. As for Test 1, a classical approach, based on the trajectories of the hands and an eFoR, would not have made it possible to unfold this phenomenon, which on the contrary appears when using Typannot.

4 CONCLUSIONS

Typannot is a SLs representation system that wants to satisfy 5 basic criteria for transcription: readability, writability, searchability, genericity and modularity. To meet these criteria, it is based on a rigorous protocol for creating characters which makes it possible to obtain a system having at the same time a robust graphematic and a coherent typographic formula.

The use of the novel TranSys Typannot makes it possible to understand the SLs signifier form in a new light that emphasizes features of the SLs which remained hidden with the previous TranSys. This is shown by the MOV analysis, based not on the trajectory of the hands in an eFoR, but on the observation of the movement propagation flow on the different SEGs and DoF, in an iFoR and from a steadied LOCini.

Two hypotheses have been tested with Typannot on a short corpus allowing to obtain some preliminary but promising results.

In the first place, it has been shown that the motor control necessary for the realization of the signs can be reduced to very simple motor schemes (1 DoF on 1 SEG) for the parameter which appears as the most unstable, i.e. MOV. This observation is only detectable if we adopt iFoR.

Subsequently, it was highlighted how the LOCini participates in the conditions of realization of the sign standardization. This standardization goes through a simple motor scheme, requiring only minimal motor control. This is the case here for more than 90% of signs.

These data, obtained thanks to Typannot, open the way to other hypotheses, for example that the preparation phase of LOCini is probably more unstable, more complex and with a greater occurrence of $FLOW^{Prox \rightarrow Dist}$ compared to the MOV deployment phase. These hypotheses need to be verified through recordings made with MoCap.

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