Extending AZee with Non-manual Gesture Rules for French Sign Language

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Abstract

This paper presents a study on non-manual gestures, using a formal model named AZee. This is an approach which allows to formally represent Sign Language (SL) discourses, but also to animate them with a virtual signer. As non-manual gestures are essential in SL and therefore necessary for a quality synthesis, we wanted to extend AZee with them, by adding some production rules to the AZee production set. For this purpose, we applied a methodology which allows to find new production rules on a corpus representing one hour of French Sign Language, the *40 brèves* (Challant and Filhol, 2022). 23 production rules for non-manual gestures in LSF have thus been determined. We took advantage of this study to directly insert these new rules in the first corpus of AZee discourses expressions, which describe with AZee the productions in SL of the *40 brèves* corpus. 533 non-manual rules were inserted in the corpus, and some updates were made. This article proposes a new version of this AZee expressions corpus.

Keywords: Sign Language Modelling, French Sign Language, AZee, Non-manual gestures

1. Introduction

Still today, Sign Languages (SLs) are considered under-resourced languages. The development of software tools dedicated to these languages is more complicated than for spoken languages. Indeed, there is no widely-accepted, broadly-adopted and officially-recognised written form for SLs, so we mostly have to work with videos, which is more difficult than working with text. Also, SLs are altogether less described than spoken languages.

Moreover, in SL studies, non-manual gestures are relatively under-researched: although everyone recognises their importance, stronger focus is still placed on the hands' activity. However, non-manual gestures are an integral part of language and convey information of potentially equal importance compared to manual ones (Crasborn, 2006; Pfau and Quer, 2010). The work on non-manual gestures is therefore crucial, especially for synthesis with virtual signers: it has been proven that facial expressions considerably help Deaf people to understand signing avatars (Huenerfauth et al., 2011). Despite this, current synthetic avatars[1] are still not providing enough in this domain. An overview of this problem has been produced by Wolfe and McDonald (2021).

Furthermore, there is linguistic work reviewing the various non-manual gestures that can be encountered in a SL discourse. The focus is usually on a specific articulator such as the mouth (Lewin and Schembri, 2011), eyebrows (de Vos et al., 2009) or head-shake (Pfau, 2008), and in general linked to one grammatical phenomenon in particular such as questions (Schalber, 2006), conditional clauses (Reilly et al., 1990) or negation (Zeshan, 2004).

As we need improvements of avatars' non-manual gestures for a more natural and comprehensible rendering, and as non-manual gestures are not described with a formal approach to improve this, we choose to work with AZee, which is a formal model allowing synthesis with avatars. The topic of non-manual gestures with AZee started to be discussed in (Filhol et al., 2014), in the early days of AZee. Since that time, a few production rules relating to non-manual gestures have been suggested, for instance `inter-subjectivity`, `intensity` or `long` (Challant and Filhol, 2022). However, no large study was conducted on this topic, and there were still many non-manual rules to be identified. We wanted to search for the production rules accounting for non-manual gestures and add them to the AZee production set.

Section 2 below presents AZee and the methodology used to find new production rules. In section 3, we present the application of this methodology on a corpus of French Sign Language (LSF), called *40 brèves*. Section 4 then presents the set of AZee production rules for non-manual gestures found by applying the methodology, which served to extend the reference corpus of AZee discourse expressions. We also give observations on the corpus. Then, in section 5, we propose some corrections on the AZee discourse expressions corpus, as well as a harmonisation of the AZee production set. Finally, we expose our conclusions and

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[1] In contrast to avatars animated by motion capture which can nowadays be quite realistic (Kim et al., 2023)

prospects for this work in the last section.

2. AZee

2.1. Presentation of the approach

AZee is a formal approach which allows to describe SL discourse (Filhol, 2021; Filhol, Hadjadj, and Choisier, 2014). At the core level, it is a functional language that can be used to precisely describe movements, body articulations enabling virtual signer animation for example, thanks to points and vectors of the signing space, timed postural constraints, etc.

On a higher, linguistic level, relevant to us, AZee allows to associate meaning with forms described in that way. Doing so creates what is called a *production rule*: a function which represents an interpretable meaning and which produces a set of observable forms. The set of all the production rules found for a specific SL (in our case, LSF) is called the *AZee production set*.

One can combine production rules to create *AZee discourse expressions*, which formally represent discourses of any length in SL.

```
1  :info-about
2      'topic
3      :organiser
4      'info
5      :side-info
6          'focus
7          :élection
8          'info
9          :président
```

Figure 1: AZee discourse expression meaning 'the organisation of the presidential elections'

We give an example of an AZee discourse expression in figure 1, which is the combination of several production rules:

- two rules with two mandatory arguments:

  I. 1 `info−about`(*topic, info*) meaning 'an *info*, which is focused, is given about *topic*'

  I. 5 `side−info`(*focus, info*) meaning '*focus*, with an additional, non-focused *info* given about it'

- three rules with no mandatory arguments and which are named after their meaning:

  I. 3 `organiser` (to organise)

  I. 7 `élection` (election)

  I. 9 `président` (president)

This AZee discourse expression means 'the organisation of the presidential elections' in LSF and generates the associated forms. It is a short extract of the 1E-VF news item, from the corpus we present in section 3.1.

2.2. Methodology

A methodology has been developed to identify production rules, based on the manual study of SL corpora. It consists of researching, alternatively, criteria of form (e.g. 'juxtaposition of two items'; 'movement of the index between right and left') and criteria of meaning (e.g. 'notion of multiplicity'; 'negation of something') until a single form for a searched meaning is found (Hadjadj, Filhol, and Braffort, 2018; Martinod, Danet, and Filhol, 2022).

The methodology in question starts with a criterion of form or meaning that we choose to study. Figure 2 illustrates this, starting with m_1, say a criterion of meaning. The first step consists of searching all the occurrences of m_1 in the corpus, and describing, for each occurrence, a set of forms associated to m_1. Different groups of identical forms are then constituted: e.g. $f_1 + f_2$ in figure 2.

These each become the starting criterion of a new separate iteration. For these new iterations, the aim is now to describe the meaning associated to the listed occurrences. In figure 2, we see $m_2 + m_3$ for f_1, and $m_4 + m_5$ for f_2.

Then, the process continues until a single set of forms is found for all occurrences of a meaning. For example, f_2 for occurrences of meaning m_2 (figure 3.2, in the top right-hand corner). For the m_2 criterion, the forms have always the same meaning f_2, which corresponds to the forms found in the first iteration: it is a case that can happen. A new production rule PR1 associating m_2 to f_2 can be created.

Sometimes, paths can merge during the process. For instance, as we can see in the figure 2, the same meaning m_3 is found when searching for occurrences of f_1 and f_2, two different form criteria. A new iteration is then realised with m_3 as a criterion of meaning, and a new set of forms f_3 is identified: a new production rule can be created, PR2.

In the next section, we explain the application of this methodology on a LSF corpus.

3. Application of the methodology on a corpus

3.1. Corpus selection

The first step to apply the methodology above is to choose a corpus. We decided to work with the corpus called *40 brèves*, the second version of which was published in 2022 by Challant and Filhol.
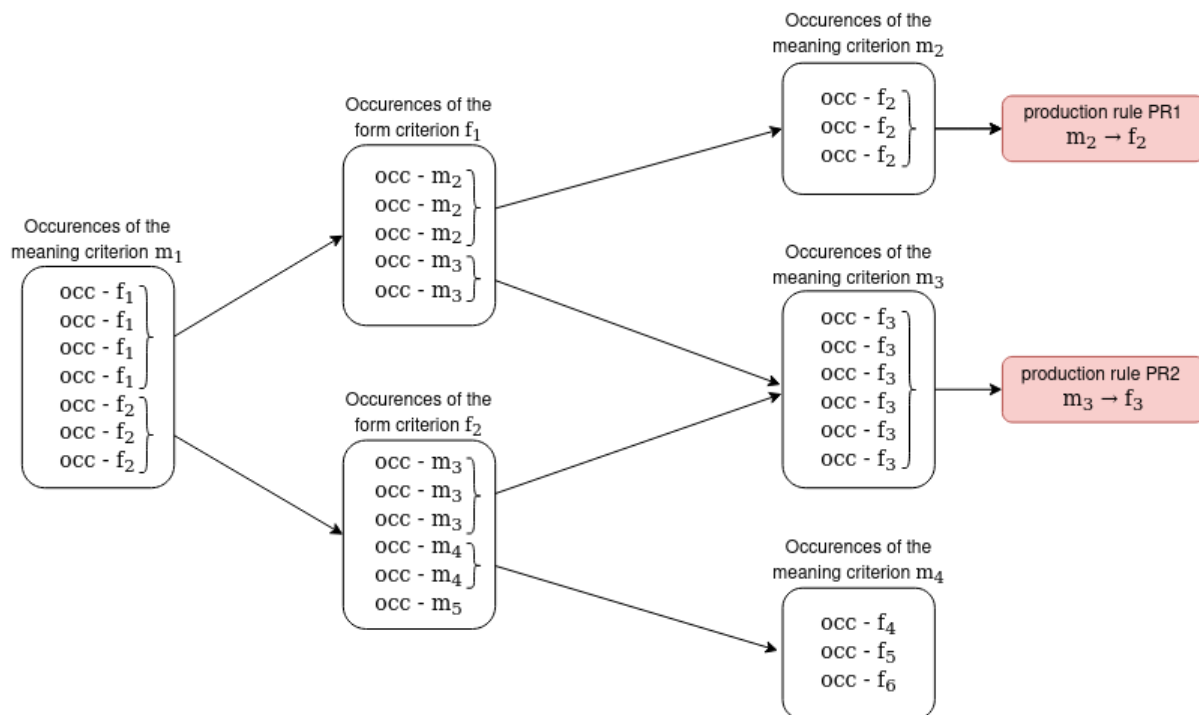
Figure 2: Illustration of the AZee methodology when seeded with a meaning criterion (m_1)

It is a parallel corpus that aligns:

- 40 short news items in written French;

- 120 videos in LSF: each of the 40 news items has been translated by three deaf professional translators, which represents a total of one hour of SL;

- 120 AZee discourses expressions, formally representing the 120 videos of LSF in AZee (without production rules for non-manual gestures in the 2022 version)

The journalistic genre of the corpus is interesting because it allows a wide range of topics to be covered and it strives to ensure canonical language, with no errors or disfluencies. It also ensures a neutrality: the non-manual gestures expressed by the signers are therefore likely to be semantically relevant content, instead of the signer's opinion, which might be possible with other genres.

Moreover, this corpus includes several signers, which is a real advantage when searching for new productions rules. This allows us to ensure that a rule is not specific to a signer in particular.

3.2. Application of the methodology

We applied the methodology presented in section 2.2 on the corpus. Two people, speakers of LSF, were involved in the process, for an approximate total of 200h of work. We took the criterion

of form 'non-manual gestures, simultaneously produced with hands activity' as the starting criterion. We were interested by facial expressions but not only: we took into account the movements of the chin, the chest or even the shoulders.

We used a basic software that allows us to watch the different videos frame by frame, in slow motion, to be able to watch the signers' movements in detail but also at normal speed to understand the speech rhythm and better grasp its meaning.

During the application of the methodology, it was very difficult to describe the set of forms observed precisely with words because the forms differences are really subtle. If we take the example of the eyebrows, they can have a multitude of positions, and not only the three "lowered", "neutral", "raised". The different positions being really hard to describe, we mainly made use of screenshots from the videos to help us in our process. The challenge in terms of meaning is not to let ourselves be influenced by the meaning given by what is signed with the hands.

During the iteration process, some groups merged together, as explained in the figure 2 with the meaning criterion m_3 which is found in two different groups of forms f_1 and f_2 and merge in one group with the set of forms f_3. For instance, we identified for two meanings, namely 'concentration' and 'interrogation', the same set of forms 'the chin moves forward, the eyebrows are furrowed and the lips are pursed'. We then found a common meaning denominator for the two meanings, and the production rule `closer-look` has been determined.

(a) `almost-reaching` (b) `big-threatening` (c) `closer-look`

Figure 3: Illustration of the forms of three productions rules for non-manual gestures

After applying the methodology, we made several choices regarding the inclusion of production rules in our AZee production set. First, we decided to consider a production rule as a standalone only if the non-manual gestures are observed to bring meaning that is different to what is accompanied by the hands. Otherwise, we considered the non-manual rule to be a part of the sign. Indeed, the core of the AZee approach is the form–meaning association, regardless of which articulators are involved in the necessary forms. There is therefore no theoretical reason to separate in two different production rules what is signed by the hands and what is signed by non-manual articulators, if they work jointly to build the same semantics.

For instance, during the application of the methodology on the corpus, we noticed a facial expression that conveys the meaning 'suspiciously'. This facial expression only appeared on the activity of the hands meaning 'suspicion'. Incidentally, this was also true the other way around: 'suspicion' never appeared without that facial expression. We therefore considered that the facial expression was baked in the sign `suspicion`, without creating a new production rule `suspiciously` because it did not live anywhere independently. The same phenomenon also occurred on the sign `approximately`, which was always observed with the same facial expression.

Then, while the majority of the production rules we found were observed with the three signers of the corpus (which helps to give us confidence in the robustness of the rules), we realised that some candidate production rules were only observed in the productions of one of the signers. In such case, when the meaning was too subtle or difficult to interpret, e.g. the overall meaning virtually unaffected by the gesture, we decided to discard it and relate it to the signer's style instead of adding a rule to the production set. This was the case, for example, with the frequent eye widening gesture produced by signer OC.

Finally, we had sometimes only one or two occurrences of a production rule in the whole corpus, and as the forms and the meaning are difficult to distinguish when we cannot compare several occurrences, we have preferred not to include these occurrences in our production set. It is the case for some rules initially found with meanings 'undoubtedly', 'hard-to-believe' or 'affected'.

The next section presents the full set of production rules for non-manual gestures found and added to the LSF production set, together with some observations about its use in the corpus.

4. Results

We found 23 production rules related to non-manual gestures. All of them have a single argument, which we called *sig* in all cases.

Each production rule listed below is named after its meaning. Screenshots illustrate the forms of the first three rules in figure 3, but a screenshot is not enough to capture the whole movement and to get the exact forms of the rules. To overcome this, we give in brackets an example of each rule in context. We provide the identifier of the news item which the example can be found (e.g. 1A-JP), followed by time markers to situate the example in the video in seconds and by the corresponding line in the AZee expression.

Here is the list of the 23 non-manual rules:

- `almost-reaching`
  (2H-OC, time: 26.56–27.00, line 215)

- `big-threatening`
  (2R-VF, time: 01.44–02.12, line 18)

- `closer-look`
  (2J-VF, time: 29.52–31.00, line 222)

- `continuously`
  (2K-OC, time: 18.32–18.84, line 155)

- `decidedly`
  (1K-JP, time: 32.24–33.08, line 237)

- `do-you-realise`
  (2Q-JP, time: 32.28–33.44, line 274)

- `impressive-grandiose`
  (1J-JP, time: 10.96–11.92, line 93)

- `inter-subjectivity`
  (1B-OC, time: 22.24–23.08, line 175)

- `it-is-a-shame`
  (2H-JP, time: 32.36–33.72, line 279)

- `most-probably`
  (1R-JP, time: 15.08–16.88, line 137)

- `much-almost-too-much`
  (1A-JP, time: 06.28–08.52, line 37)

- `nothing-sticks-out`
  (2D-JP, time: 09.04–10.08, line 67)

- `peacefully`
  (1R-JP, time: 14.36–15.48, line 127)

- `something-sticks-out`
  (2O-JP, time: 29.24–29.08, line 191)

- `takes-a-while`
  (2R-OC, time: 23.92–24.84, line 256)

- `too-scared-to-look`
  (1O-VF, time: 17.00–17.72, line 43)

- `trouble-disturbance`
  (2Q-JP, time: 29.12–30.28, line 252)

- `uneasy-awkward`
  (1C-JP, time: 25.36–26.04, line 250)

- `with-chaos`
  (1F-OC, time: 09.44–10.28, line 97)

- `with-no-precision`
  (2C-VF, time: 05.24–06.16, line 39)

- `with-surprise`
  (1E-JP, time: 29.28–30.28, line 240)

- `with-uncertainty`
  (2R-VF, time: 25.88–26.56, line 243)

- `with-worry`
  (1B-VF, time: 20.48–22.02, line 175)

Once this rule set established, we complemented the *40 brèves* corpus with the appropriate applications of the new production rules. We have made it publicly available as a new version (v3) on the Ortolang platform[2]. In total, 533 occurrences of the rules concerning the non-manual gestures can
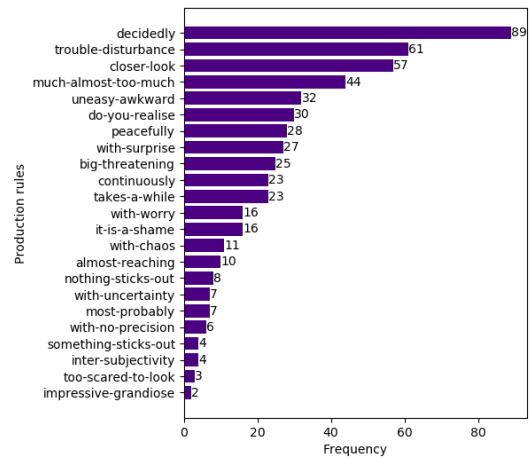
Figure 4: Frequency of the non-manual production rules

now be counted in the corpus. Figure 4 presents the frequency of the different production rules in the corpus: each rule appears between 2 and 89 times.

In figure 4, we can see that the most frequent rules for non-manual gestures are `decidedly`, `trouble-disturbance`, `closer-look`, `uneasy-awkard`. We do not drive to any conclusions about this ranking in particular, the semantics of those rules likely being mostly a reflection of the contents of the corpus, i.e. news about hostages, natural disasters and rebellion against power in a significantly large proportion.

We have noticed some interesting uses of the non-manual production rules, we detail a few cases below. First, we want to emphasise that the rules present in the corpus have a real semantic contribution: they are necessary to understand the full message of the discourse.

```
:it-is-a-shame
    'sig
    :info-about
        'topic
        :non tête
        'info
        :il n'y a pas
```

Figure 5: 2H-JP discourse expression extract, exhibiting a rule whose generated non-manual form is necessary to the overall meaning

For example, as illustrated in figure 5, the meaning of the production rule `info-about` applied to arguments `non tête` (no with a head shake) and `il n'y a pas` (there is none/nothing) is completely different when wrapped inside the non-manual rule `it-is-a-shame`. The signer here is talking about the absence of a new star on

the French football players' jersey after a defeat against Italy, which is a shame for the French team. The fact that the missed victory is regrettable only comes from the use of `it-is-a-shame`.

```
:decidedly
    'sig
    :with-chaos
        'sig
        :attaquer
            'patient
            ^Lssp
```

Figure 6: AZee discourse expression with non-manual rules which are combined (from 1N-JP)

We also observed non-manual rules combining and layering their respective meanings and forms. For instance in figure 6, `decidedly` and `with-chaos` are combined and wrapped around a sign meaning 'attack' directed to a point on the left-hand side of the signing space (`Lssp`).

```
:not-but
    'negated
    :much-almost-too-much
        'sig
        [sales]
    'correction
    :trouble-disturbance
        'sig
        [sales poorly profitable]
```

Figure 7: AZee discourse expression with non-manual rules in contrast

Like any other construction, expressions with non-manual rules are also used inside elaborate constructions, e.g. in the 2L-OC news item (figure 7). In this instance meaning 'sales have not been [as] abundant [as expected]', rule `not-but` already presents a contrast between its two arguments. The contrast is reinforced by the use of a non-manual rule on each one: `much-almost-too-much` on "sales" to mean 'abundant sales' (negated by `not-but`), and `trouble-disturbance` on "sales poorly profitable" (the correcting statement to consider instead).

We present in the next section some updates we propose for the AZee expressions corpus.

5. Differences with previous version

We now list some further differences brought to the corpus with the extension. They mostly come from corrections made, and a harmonisation of the production set.

First of all, there were in the corpus some ellipses (indicated by a %E in the corpus), which indicated the non-covered parts with AZee of the corpus. There were 334 instances of ellipses in total.

In these 334 ellipsis, there were 207 ellipses annotated with *multiplicity*. Indeed, some parts were annotated with one meaning, the idea of plurality, but corresponded to several forms: this does not correspond to the definition of a production rule. A study has been conducted by Martinod et al. (2022) after the publication of the first version of the corpus, leading to the creation of two new production rules:

- `mult-around`*(item, loc)*: multiple instances of *item* scattered or spread out on a surface around loc, with the exact count unknown

- `mult-in-a-row`*(item, path)*: multiple instances of *item* aligned along path, with the exact count unknown

We have been able to replace 152 of the 207 ellipses *multiplicity*. We found 81 occurrences of `mult-around` and 57 of `mult-in-a-row`. However, 56 ellipses *multiplicity* remain in the corpus. In addition, there are 120 ellipses remaining, aside from *multiplicity* ellipses.

Then, we wrote some *path* thanks to three of the new AZee operators : *curve* (list of points of the signing space), *arcfrom* (starting point, centre point, normal vector, revolution count) and *straight-between* (two points of the signing space).

We remind that these are AZee native operators, not production rules. These operators allow to create geometric paths using points and vectors in the signing space. For instance, for a plane that takes off from the ground or a set of regions deployed in signing space. In others words, these kind of operators allow to formally describe things created on the fly by the signer, a typical phenomenon in SL.

We can also compare the two versions of the AZee expressions corpus. The second version of the corpus includes 12,452 named production rules in total, i.e. 982 more than in the first version. Figure 8 gives an update of the production rule frequencies measured in the corpus, restricted to those defined with at least one mandatory argument. We see that the most frequent rules are mostly the same as in the first version (see Challant and Filhol (2022)): `info-about`, `side-info`, `instance-of`... The rules appear in the same proportion than in the first version. Nevertheless, five new rules figure in the top 20: `decidedly`, `trouble-disturbance`, `closer-look`, as well as `mult-around` and `mult-in-a-row`.

Finally, in the corpus version (v3) we propose, we decided to rename some production rules, in order to harmonise the production set. This was not
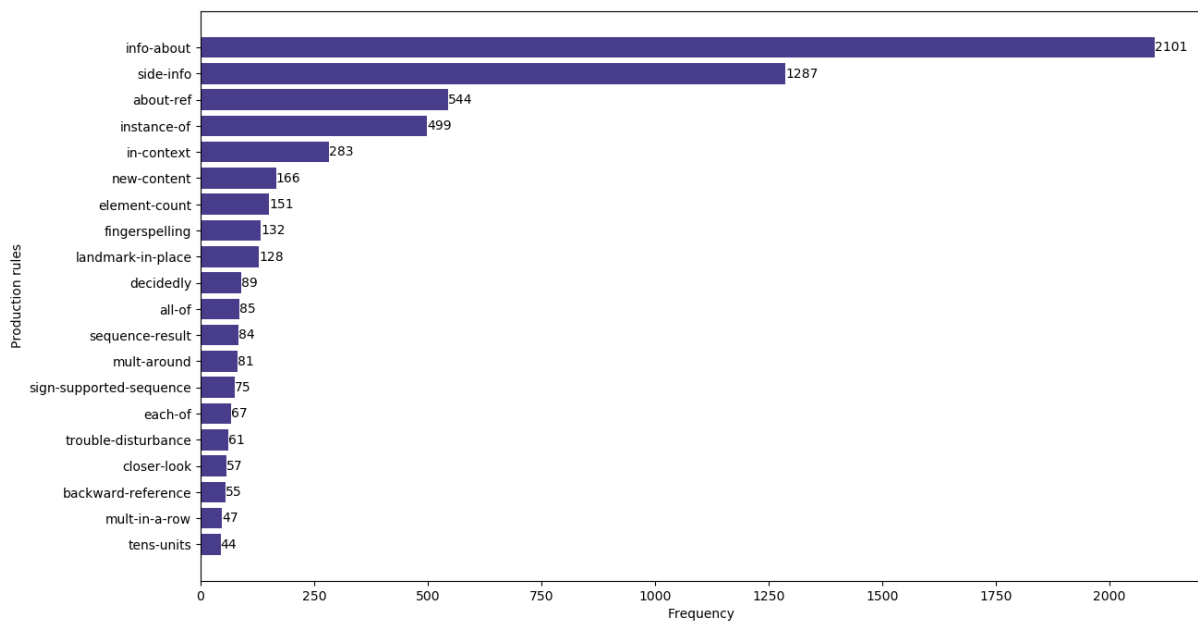
Figure 8: Frequency of the 20 most used production rules in the corpus

a necessary step from a theoretical point of view, but we eventually considered it more elegant and useful for future AZee users. In particular, all rules with at least one mandatory argument (those structuring the expressions) were given English names. The rules with no mandatory arguments remain in French because their names resemble glosses and it is customary in the scientific community and among users of a SL to use the written language of its territory. All the production rules with at least one mandatory argument which are used in the corpus are available in appendix A (without the production rules for non-manual gestures that we have already presented in section 4).

6.   Conclusion and prospects

To conclude, this paper presents the study we conducted on a phenomenon that has never been thoroughly studied using the AZee approach, namely non-manual gestures. We explained the methodology which allows to find new AZee production rules, and we presented its application on the *40 brèves* corpus. 23 production rules were found which augmented the currently known production set for LSF.

We complemented the AZee part of the corpus by inserting these rules where appropriate, and made this new version available. Incidentally, we also propose a few updates to the corpus, in the places where AZee has matured, and updated the names used in the rule set.

The prospects for the work presented in this paper can be divided into three main areas. The first one concerns synthesis with virtual signers.

Since every rule specifies both the forms to be produced and their relative timing, the expressions can directly be animated on an avatar, including the added non-manual features. This now seems in close reach thanks to the recent efforts like the facial expression builder created by McDonald et al. (2022) or the synthesis through Blender (Sharma et al., 2024).

Secondly, we are aware that we worked on a small corpus and with a particular genre, so it is likely that more non-manual rules exist, that were not present in our corpus. We would like to work on other types of corpus, to maximise coverage of these features. This would even enable comparison between genres. For instance, discourses with more iconic structures, like descriptions of scenes (e.g. *Mocap1* (Benchiheub et al., 2020)) or story telling (e.g. *LS-COLIN* (Cuxac et al., 2014)).

Thirdly, this work on non-manual gestures can be analysed from a formal linguistic point of view. Various tests can be carried out on the new version, and questions raised such as: are there regular patterns for the non-manual rules or their context? Is it possible to have very large expressions under these rules? Or do they tend to contain shorter productions?

Ethical Statements

The pictures of figure 3 are taken from the *40 brèves* corpus, which is under a CC BY-NC-SA 4.0 Deed license.

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A. AZee production set

This appendix displays a set of production rules containing all those appearing in the *40 brèves* corpus extension (v3), in alphabetical order, excluding those listed in section 4 (accounting for non-manual gestures).

- about-ref(*pt, sig*): *sig* about the reference of point *ref*

- all-of(*items*): set of *items*, with focus on the set as a whole

- backward-reference(*ptr, sig*): immediately refer back to the just-signed *sig* with pointer *ptr*

- cam-switch(*povs*): list of different points of view *povs* on the same event

- character-switch(*char, sig*): *sig*, in the specified *char*

- deploy-shape(*class, path*): sobject denoted by *class* is deployed along *path*

- double-letter(*letter*): a doubled *letter* in a spelling sequence

- each-of(*items*): list of *items*, each given equal focus

- elt-count(*count, elt*): *count* instances of *elt*

- fingerspelling(*letters*): word spelt with *letters* in order in written language

- from-date-to-date(*date1, date2*): period of time between dates *date1* and *date2*

- in-context(*context, process*): *process* takes place in the context *context*

- info-about(*topic, info*): *info*, which is focused, is given about a *topic*

- instance-of(*type, elt*): *elt*, to interpret as an instance of *type*

- interrupted-process(*proc*): *proc* but not quite, or intentionally interrupted

- landmark-in-place(*lm, sig*): *sig* is constructed around fixed landmark *lm* positioned in space

- mult-around*(item, loc)*: multiple instances of *item* scattered or spread out on a surface around loc, with the exact count unknown

- mult-in-a-row*(item, path)*: multiple instances of *item* aligned along path, with the exact count unknown

- number-mult(*nums*): number whose value is the product of the list *nums*

- number-sum(*nums*): number whose value is the sum of the list *nums*

- new-content(*sig*): recollecting thoughts, taking breath, rhethorical break before *sig* (generates relaxation, hand clasp)

- not-but(*negated, correction*): not *negated* but *correction*

- open-list-non-mutex(*items*): non-exhaustive list of non mutually exclusive *items*

- place-object(*class, loc*): object denoted by *class* is placed at location *loc*

- reposition-object(*class, src, dest*): object denoted by *class* is moved from *src* to *dest*

- reversed-process(*proc*): reverse meaning of *proc*

- sequence-result(*sig1, sig2*): *sig2* occurs on the condition that *sig1* has happened/finished, or *sig1* triggers *sig2*

- side-info(*focus, info*): *focus*, with an additional, non-focused *info* given about it

- sign-supported-sequence(*units*): *units* concatenated in order in an outside linear system, e.g. dates using day–month–year format, math script reading a formula, sign supported French using words...

- simultaneous(*sig1, sig2*): *sig1* and *sig2* are true at the same time

- tens-units(*tens, units*): the number formed of the two digits *tens* and *units*

- year-count(*count*): age/duration of *count* years