frontiers | Frontiers in Language Sciences

TYPE Original Research
PUBLISHED 10 January 2023
DOI 10.3389/flang.2022.1052205

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Language Processing, a section of the journal Frontiers in Language Sciences

RECEIVED 23 September 2022
ACCEPTED 12 December 2022
PUBLISHED 10 January 2023

CITATION
Minor S, Mitrofanova N, Guajardo G, Vos M and Ramchand G (2023) Aspect processing across languages: A visual world eye-tracking study. *Front. Lang. Sci.* 1:1052205. doi: 10.3389/flang.2022.1052205

Aspect processing across languages: A visual world eye-tracking study

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The study employed a combination of a picture selection task and Visual World eye-tracking to investigate the processing of *grammatical aspect* (perfective vs. imperfective) in three languages: Russian, Spanish and English. In order to probe into the cognitive representations triggered by the aspectual forms we contrasted visual representations of different temporal portions of telic events—a snapshot of the process stage (ongoing event) and a snapshot of the immediate aftermath of the event/the result state (completed event). In all three languages, the gaze patterns and offline responses revealed a strong preference for representations of ongoing events in the imperfective condition. This confirms that the imperfective forms in all the three languages draw attention to the in-progress portion of a telic event. In the perfective condition, however, we found robust differences. Russian uses verbal prefixes to mark perfective aspect, and our results suggest that perfective telic verbs in Russian strongly highlight the result state of an event. In Spanish, the perfective past tense form (Preterite) also highlights event completion, but to a lesser extent than in Russian—in line with its less restrictive semantics in not requiring an inherent boundary. In contrast to Russian and Spanish, English speakers did not show a preference for representations of completed events in the perfective (Simple Past) condition. This suggests that the English Simple Past form does not encode a preferential cognitive salience for either the activity portion of an event or its result state, and lends support to the analysis of the English Simple Past as a non-aspectual tense form.

KEYWORDS

grammatical aspect, perfectivity, grammatical processing, VW eye-tracking, cross-linguistic comparison

1. Introduction

Grammars of many languages possess a means of encoding *grammatical aspect*, drawing a distinction between *perfective* and *imperfective* verb forms. In the theoretical literature, this opposition has been linked to the notions of *event completion* and/or *boundedness* (Comrie, 1976; Dahl, 1985; Smith, 1991). On this view, perfective forms are used to represent entire events including the endpoint, while imperfective forms focus on internal portions of an event, possibly excluding the endpoint. Thus, for events that possess a natural endpoint/internal boundary (*telic events*), the perfective form conveys

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that the natural endpoint was reached. This is illustrated below with examples from Russian (1), Spanish (2) and English (3), which all possess verbal forms that have been analyzed as encoding the perfective/imperfective distinction. Examples (1-a), (2-a), and (3-a) involve verb forms that have been analyzed as perfective, and have been claimed to trigger entailments of event completion (Dowty, 1979; Parsons, 1990; Smith, 1991; Klein, 1994, 1995; Altschuler, 2014; Arche, 2014; Martin and Gyarmathy, 2019). Upon hearing these sentences listeners are expected to infer that Marta completed the drawing of the castle. On the other hand, the minimally different sentences in Examples (1-b), (2-b), and (3-b) involve verb forms that have been analyzed as imperfective, and the sentences do not give rise to inferences of event completion (Marta may have stopped before she completed the drawing).

(1) a. Marta na-risova-la zamok.
Marta PFV-draw-PST.F.SG castle
'Marta drew a castle.'

b. Marta risova-la zamok.
Marta draw.IMP-PST.F.SG castle
'Marta was drawing a castle.'

(2) a. Marta dibuj-ó un castillo.
Marta draw-3S.PRET a castle
'Marta drew a castle.'

b. Marta dibuj-aba un castillo.
Marta draw-3S.IMP a castle
'Marta was drawing a castle.'

(3) a. Marta drew a castle.

b. Marta was drawing a castle.

Previous behavioral studies on the processing of grammatical aspect have confirmed the theoretical intuition that the contrasting categories of perfective vs. imperfective have the effect of "focusing" on different conceptual portions of the event description. Imperfective aspect focuses on the in-progress, activity stage of an event, while Perfective aspect triggers a representation of the event as a completed whole, thus highlighting the final stage and/or the result (goal) state of the event (Madden and Zwaan, 2003; Ferretti et al., 2007; Madden and Therriault, 2009; Zhou et al., 2014). Because Imperfective aspect highlights the details of the activity stage of the event, this leads to a higher availability of features associated with the activity, including participants, instruments and locations (Carreiras et al., 1997; Ferretti et al., 2007). Furthermore, Bergen and Wheeler (2010) found that verbs in the Imperfective aspect exhibit a congruency effect with the direction of motor movement, suggesting that they trigger a motor simulation of the described activity.

Abbreviations: PFV, perfective; IMP, imperfective/imperfect; PST, past tense; PRET, preterite; SG, singular; 3S, third person singular; F, feminine.

The perfective-imperfective distinction has also been argued to play a role in discourse structuring (Hopper, 1979, 1982), with perfective forms used to mark foregrounded events that follow each other in the narrative sequence, and imperfective forms used for backgrounded events that temporally overlap with other events in the narrative. This property is illustrated in the following Examples (4) for Russian, (5) for Spanish, and (6) for English:

(4) a. Kogda ja po-tuši-l kostër,
when I PFV-put.out-PST.M.SG campfire
načals^{j}a dožd^{j}.
start.PFV.PST.M.SG rain
'When I extinguished the campfire, it began to rain.'

b. Kogda ja tuši-l kostër,
when I put.out.IMP-PST.M.SG campfire
načals^{j}a dožd^{j}.
start.PFV.PST.M.SG rain
When I was extinguishing the campfire, it began to rain.'

(5) a. Cuando apagu-é la fogata, empez-ó
when put.out-1S.PRET the fire, start-3S.PRET
a llover.
to rain
'When I extinguished the fire, it began to rain.'

b. Cuando apag-aba la fogata, empez-ó a
when put.out-1S.IMP the fire start-3S.PRET to
llover.
rain
'When I was extinguishing the fire, it began to rain.'

(6) a. When I extinguished the campfire, it began to rain.

b. When I was extinguishing the campfire, it began to rain.

In Examples (4-a), (5-a), and (6-a) the verb forms in the *when*-clauses are perfective, and the sentences are understood as describing a sequence of events where the extinguishing of the campfire precedes the event of the rain starting. In contrast, in Examples (4-b), (5-b), and (6-b) the verbs in the *when*-clauses are imperfective, and the fire-extinguishing event is understood as overlapping with the event of the rain starting (i.e., the rain started within the time period that the extinguishing event was taking place).

An actively debated question concerns the nature and extent of variation between aspectual systems across languages. Is there a unified grammatical category of "perfective" that can be applied to all forms that exhibit the characterisitic properties described above (and similarly for "imperfective," Dahl, 1985)? For instance, do all perfective forms trigger entailments of event completion in the same way, or is there variation in the strength of such entailments? It has been noted that in

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some languages perfective forms of telic verbs are consistent with non-completion (Li and Thompson, 1981; Singh, 1991; Koenig and Muansuwan, 2000; Bar-el et al., 2005). This has prompted a distinction between "strong" perfective forms that entail event completion, and "weak" perfective forms that merely convey that the event ceased, without necessarily reaching its natural endpoint (Martin and Gyarmathy, 2019). In this study, however, we were interested in exploring potential variation between languages that have been classified as possessing strong perfectives, focusing on Russian, Spanish and English.

In Russian, all verbs are marked as perfective or imperfective. Morphologically, there are two main ways of marking the aspectual contrast. Perfective verbs can be derived from Imperfective verbs *via* the addition of a prefix (e.g., *risova-* "to draw^{IMP}" vs. *na-risova-* "to draw^{PFV})." Conversely, Imperfective verbs can be derived from Perfective verbs *via* the addition of an imperfectivizing suffix (*-va, -yva, -a*) that precedes the tense/agreement inflection (these verbs are sometimes referred to as "secondary imperfectives," e.g., *ot-rky-* "to open^{PFV}" vs. *ot-rkry-va-* "to open^{IMP}").[1]

Previous offline judgement studies have shown that the use of perfective telic verbs such as *narisova-* "to draw^{PFV}" Example (1), *pročita-* "to read^{PFV}" Example (4) and *otrkry-* "to open^{PFV}" Example (12), in contrast to their imperfective counterparts, trigger a representation of the event as a completed whole, highlighting the final stage and/or the result state of the event (Stoll, 1998; Vinnitskaya and Wexler, 2001; Kazanina and Philips, 2007). These findings are consistent with the common theoretical claim that such verbs strongly entail that the event reached an internal boundary (Vinogradov, 1947; Forsyth, 1970; Bondarko, 1983; Maslov, 1984; Timberlake, 2004).

In Spanish, the perfective-imperfective distinction is manifested in the opposition between *preterite* and *imperfect* past tense forms (Bosque, 1990; Bybee, 1995; Borik and González, 2001; González, 2003; Fábregas, 2015). Verbs in the preterite form indicate that the corresponding event reached a final boundary, i.e., ceased to occur. In the case of telic predicates, and in the absence of indications to the contrary, this can be taken to mean that the event was completed. Thus, del Real (2015) conducted a series of experiments on children's L1 acquisition of Spanish aspectual contrasts, using adult speakers as controls. In tasks matching sentences with pictures, adults systematically associated preterite verb forms with completed situations and imperfect forms with incomplete and ongoing situations, in both narrative and out of the blue contexts.

However, in the case of the Spanish preterite, completion is not a necessary entailment. For instance, Arche (2014) reports that most Spanish speakers find the following sentence contradictory, indicating that the verb in the preterite is interpreted as conveying completion of the castle-coloring event:

(7) #Marta colore-ó un castillo, pero no lo
Marta color-3S.PRET a castle but not it
termin-ó.
finish-3S.PRET
Marta colored a castle, but she did not finish it.'

However, in the presence of an adverbial that imposes a temporal boundary on the duration of the event (e.g., *for ten minutes*), the completion interpretation is easily canceled. Thus, the following sentence no longer produces a contradictory effect:

(8) Marta colore-ó un castillo durante diez minutos,
Marta color-3S.PRET a castle for ten minutes
pero no lo termin-ó.
but not it finish-3S.PRET
'Marta colored a castle for ten minutes, but she did not finish it.'

In contrast, Russian disallows the use of perfective verbs like *raskrasi-* 'to color^{PFV}' in contexts such as (8) (Janda and Fábregas, 2019). The corresponding imperfective verb *raskrašiva-* 'to color^{IMP}' must be used instead:

(9) Marta desʲatʲ minut ras-kraši-va-la /
Marta ten minutes PFV-color-IMP-PST.F.SG /
*ras-krasi-la zamok.
PFV-color-PST.F.SG castle
'Marta colored a castle for ten minutes.'

The cancellability of the completion entailment, as well as the apparent existence of speaker- and verb-conditioned variation in the judgements of examples like Example (7) (Arche, 2014), suggests that verbs in the preterite form in Spanish do not semantically entail that the event reached its result state/natural endpoint. Instead, they entail the existence of a final boundary, which in the case of telic predicates may by default *pragmatically implicate* event completion. If this is the case, we can expect that the emergence of the completion implicature may be influenced by the lexical properties of particular verbs, as well as contextual factors and world knowledge.

This contrast between Russian and Spanish may be linked to the way the two languages formally encode perfective aspect. Thus, in Russian perfectivizing prefixes on telic verbs (e.g., *na-risova-* "to draw^{PFV}" and *pro-čita-* "to read^{PFV}") have been analyzed as directly encoding the result state within a complex event structure (on a par with verb particles in Germanic languages, see Ramchand, 2005; Svenonius, 2005). In contrast, in Spanish perfectivity is bundled together with tense in an inflectional/functional category less tightly linked to the lexical verb.

Finally, in English the contrast between *simple* and *progressive* past tense forms has been analyzed as manifesting

1 In this latter case, the imperfective verb may carry both a prefix and a suffix (e.g., *ot-rkry-va-* 'to open^{imp}). As a convention, in the examples we will gloss the prefix as pfv and the suffix as imp, see e.g., Example (12).

the aspectual opposition between perfective (Simple Past) and imperfective (Past Progressive), as illustrated in Examples (3) and (6) (Smith, 1991; Klein, 1994). While it has been commonly claimed in the theoretical literature that Simple Past forms of telic predicates give rise to completion inferences (e.g., Dowty, 1979; Parsons, 1990), a varied range of counter-examples and exceptions has been identified (Smollett, 2005; Hovav, 2008; Piñon, 2008; Deo and Piñango, 2011; Martin and Schäfer, 2017; Martin, 2019). Experimental studies have also yielded mixed results. Madden and Zwaan (2003) report that participants in a sentence-picture matching task displayed a relatively strong preference (76% of the trials) for pictures of completed events (as opposed to events in progress) when presented with sentences involving telic predicates in the Simple Past form. On the other hand, Jeschull (2007) found that in a sentence-video matching task, adult English speakers selected videos of completed events only 49% of the time when presented with sentences containing non-particle simple past telic verbs (compared to 91% for particle verbs). Similarly, in a study comparing the interpretation of aspectual forms in English and Hindi, Arunachalam and Kothari (2011) found that 47% of the time English speakers accepted sentences with simple past telic predicates as descriptions of videos depicting incomplete events. This was comparable to the weak (simple) perfective in Hindi (53%), but contrasted with the strong (complex) perfective (29%). Finally, in a small-scale picture judgement task, van Hout (2008) found that in 75% of the trials adult English speakers accepted sentences with telic predicates involving non-particle verbs in the Simple Past form (*eat his/her cheese* or *drink his/her coke*) as descriptions of incomplete events (as compared to 29% for particle verbs *eat up/drink up*).

Furthermore, the function of Simple Past forms to convey event sequencing in a narrative is restricted to non-stative predicates. Simple Past forms of statives pattern with progressive forms in signaling event overlap:

(10) When I owned those shares, the stock prices went up and down many times.

In Example (10) the predicate in the *when*-clause is stative (*own those shares*), and the event of stock prices going up and down is understood as happening within the time period that this state held—in contrast to Example (6-a) and in parallel to Example (6-b). Thus, to retain an analysis of the English Simple Past form as perfective we are forced into having two semantically different (homophonous) past tense inflections (for states and for non-states), or at least we have to stipulate that past tense statives are somehow exceptional, e.g., "non-canonical" perfectives (Smith, 1991).

The goal of the current study was to investigate the interpretation of aspectual forms across multiple languages—Russian, Spanish and English—while applying a unified experimental paradigm. We were especially interested in the semantic processing of forms that have been analyzed as "strong perfectives." To probe deeper into the interpretation of these forms we complemented offline judgements with an online measure less subject to metalinguistic awareness—eye tracking in the Visual World paradigm.

The Visual World paradigm (VWP) has been a richly productive methodology in the area of linguistic processing (Cooper, 1974; Tanenhaus et al., 1995; Allopenna et al., 1998; Altmann and Kamide, 1999; Kamide et al., 2003; Lew-Williams and Fernald, 2007). The usefulness of the paradigm stems from the general fact that human eye movements track the focus of linguistic attention, if that attention is given a visual manifestation. The specific linking hypothesis between the eye movement behavior and processing activity in the brain is still controversial, with a number of subtly different proposals contrasting mostly with respect to the relative timing and interaction between top-down and bottom-up cues to attention, and the relationship between the visual and linguistic information inputs (see Huettig, 2015 for an overview). Overall, however, the paradigm has proved to be highly sensitive to aspects of linguistic input, with eye movements tracking attention in a temporally fine grained way, beyond the conscious control of the language user.

In this study, we apply the VWP to experimentally probe into the cognitive representations triggered by the processing of grammatical aspect (perfective vs. imperfective) in three languages: Russian, Spanish and English. As we have discussed, grammatical aspect has been analyzed as a category that controls which perspective is being taken on the event described by the verb in combination with its arguments. Events or situations in the world are arguably more complex than objects in that they involve a temporal dimension and express relationships among objects/participants. In language, events are typically evoked by means of verbs, but the identity criteria for (even concrete) events are more difficult to characterize than for concrete objects. For example, the event of "eating" contains many temporal phases, each of which can look quite different qualitatively from the other. Using a static visual representation to image an event faces choices not found with object imageability, in that the event *looks different* at different points during its temporal unfolding. Aspect marking on lexical verbs is a linguistic device that is thought to be relevant to precisely the question of which portion of the event is being singled out in the description.

To represent a verbal concept in its entirety, a dynamic representation would theoretically be more satisfactory. The present study (and others that are interested in aspectual distinctions) deliberately uses two different types of *static* visual representation which focus on different temporal portions of the depicted event— a snapshot of the ongoing event, or a snapshot of the immediate aftermath of the event. If aspectual marking makes salient a particular dimension of an event, we expect eye tracking in a picture matching paradigm to track (i) the nature of that focus, and (ii) the time course of when that

choice is made. This has previously been demonstrated by Zhou et al. (2014) who employed the VWP to investigate the time course of grammatical aspect processing by Mandarin-speaking children and adults. The participants were shown two pictures: one representing an ongoing event (e.g., an old lady planting a flower) and the other representing the corresponding completed event (e.g., an old lady having planted a flower). While looking at the pictures, the participants heard sentences involving either a perfective or a durative (imperfective) morpheme, which in Mandarin always immediately follows the verb. Zhou et al. found that all groups of participants launched significantly more looks to the completed event picture in the perfective condition, and conversely significantly more looks to the ongoing event picture in the durative condition. Moreover, the results showed that the participants reacted to aspect immediately after they heard the aspectual morpheme, before all of the verb's arguments were introduced (see also Foppolo et al., 2021 for a VWP study of grammatical aspect in Italian involving a slightly different design and research questions). The present study capitalizes on these results to further investigate the processing of aspectual categories in three languages with typologically distinct systems of aspectual marking (Dahl, 1984; Bybee and Dahl, 1989). We address the following research questions:

- Do speakers of Russian, Spanish and English show offline and online preference for representations of *ongoing events* when hearing sentences involving verbs marked with imperfective aspect?
- Conversely, do speakers of Russian, Spanish and English show offline and online preference for representations of *completed events* when presented with sentences involving verbs marked with perfective aspect?
- Do the preferences triggered by perfective verb forms differ between the three languages?

2. Materials and methods

2.1. Participants

The study included three experiments with adult speakers of Russian, Spanish and English. For the first experiment, 124 adult Russian speakers (m.a. = 22) were recruited and tested in Moscow (Russia). For the second experiment, 32 adult speakers of Argentinian Spanish (m.a. = 38.25) were recruited and tested in Bahía Blanca (Argentina). For the third experiment, 66 adult English speakers (m.a. = 26.47) were tested in Edinburgh (Scotland), Trondheim and Tromsø (Norway). All the participants tested in Trondheim and Tromsø had spent <2 years in Norway prior to the experiment.

All participants had normal or corrected-to-normal vision. Informed consent was obtained from all participants prior to participation. The participants of the Russian and English experiments received money, gift cards or cinema vouchers worth $6-13 as compensation.

2.2. Materials

The experiment included 24 test items consisting of a visual display and an audio stimulus. The visual display involved two pictures presented on a screen side by side, representing two stages of the same event. One picture represented an ongoing event (e.g., a girl in the process of drawing a vase), while the other represented the corresponding completed event (e.g., the result state that obtained when the girl finished drawing the vase, Figure 1).[2]

The audio stimuli included a preamble and a test sentence, and were recorded by female native speakers of Russian, Spanish and English. The preamble sentence provided a short description of a scene in the past tense (e.g., *It was a bright and sunny day*, *It was the first period at school*, etc.), and was intended to create a narrative context for the test sentence. The use of the preamble allowed us to restrict Perfective and Imperfective verbs to their narrative readings, e.g., to exclude habitual readings, as well as so-called 'general factual' readings of imperfective verbs in Russian (Grønn, 2004). The test sentence was a transitive clause containing a subject NP (*grandma*, *grandpa*, *a girl* or *a boy*), a verb and an object NP which included an adjective and a common noun (e.g., *a slender vase*, *a new shirt*, etc.). All the verbs in the test sentences were in the past tense. A standardized 350 ms pause was inserted between the verb and the object. We manipulated the grammatical aspect of the verb: each test sentence had two versions that contained verbs with the same lexical content but differing in grammatical aspect. All test items used in the study involved telic predicates, or *accomplishments*, i.e., predicates that represent events consisting of a process stage and a well-defined result stage (Vendler, 1967; Dowty, 1979).

In the Russian experiment the test sentence involved either an Imperfective or a Perfective verb, cf. Examples (11), (12). In half of the items the aspectual distinction was encoded in a prefix [an un-prefixed imperfective verb vs. a prefixed perfective verb, Examples (11)] and in the other half it was marked by a suffix [a prefixed perfective verb vs. a prefixed+suffixed imperfective verb, Examples (12)].[3]

(11) a. Devočka risova-la tonkuju vazu.
girl draw.IMP-PST.F.SG thin vase
'The girl was drawing a thin vase.'

2 All the visual stimuli from the current study can be accessed at https://osf.io/38jz5/.

3 As part of a separate study, we tested whether the time course of aspectual processing in Russian was influenced by the specific location of aspectual marking within the verb (prefix vs. suffix). The results of this analysis are reported in Minor et al. (2022).

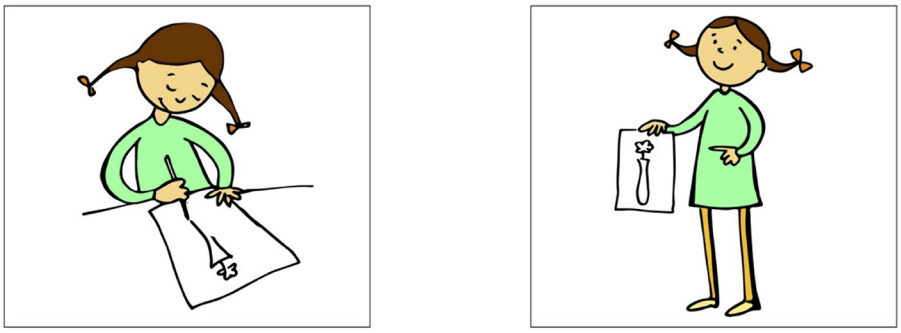

FIGURE 1
Ongoing event (OE) and Completed event (CE) pictures representing two stages of the event of a girl drawing a vase.

b. Devočka na-risova-la tonkuju vazu.
girl PFV-draw-PST.F.SG thin vase
'The girl drew a thin vase.'

(12) a. Devočka ot-kry-va-la krasivyj
grandpa PFV-dig-IMP-PST.F.SG beautiful
podarok.
present
'The girl was opening a beautiful present.'

b. Devočka ot-kry-la krasivyj podarok.
grandpa PFV-dig-PST.F.SG beautiful present
'The girl opened a beautiful present.'

In the Spanish experiment, the imperfective versions of the test sentences contained verbs in the Imperfect form, while the perfective versions involved verbs in the Preterite form, Example (14). Moreover, the test items were restricted to regular *-ar* verbs in order to constrain the morphological variability of the tense forms: all the verbs used in the test items were uniformly marked with the inflection *-aba* in the Imperfect form and *-ó* in the Preterite form.

(13) Era la primera clase en la escuela
was the first period at the school
'It was the first period at school.'

(14) a. Una nena dibuj-aba un florero delgado
a girl draw-3S.IMP a thin vase
'The girl drew a thin vase.'

b. Una nena dibuj-ó un florero delgado
a girl draw-3S.PRET a thin vase
'The girl was drawing a thin vase.'

In the English experiment, the imperfective version of the test sentences involved a verb in the Past Progressive form, while the perfective version involved a verb in the Simple Past form. The test items were selected in such a way as to avoid particle verbs (e.g., *blow up*, *chop down*, etc.), since we hypothesized that verbal particles can themselves affect the aspectual properties of verb forms (Jeschull, 2007; van Hout, 2008).

(15) Preamble: It was playtime at the school.

(16) a. The girl was drawing a slender vase.
b. The girl drew a slender vase.

Two lists were created such that each test item appeared once in each list: in the imperfective form in one list, and the perfective form in the other. Half of the test items in each list involved imperfective verb forms and half involved perfective verb forms. The position of the ongoing/completed event picture and the target picture was balanced within each list and aspectual condition. In the Russian experiment, two additional lists were created where the position of the target and competitor pictures was reversed as compared to the original lists, thus resulting in 4 lists altogether. This was done in order to balance the position of the target picture within items involving different types of aspectual marking (prefixal vs. suffixal). The participants were randomly assigned to one of the lists.

In addition to the 24 test items, each list included 24 fillers. In contrast to the test items, the visual display in the fillers included two pictures representing different types of events (e.g., *Granddad chopped down a tall tree* vs. *Granddad blew out an old candle*). Given that the pictures in the filler items represented different event types, the target picture could be identified solely on the basis of the lexical meaning of the verb. The preambles used in the fillers were the same as those used in the test items. In the Russian and Spanish experiments, the target sentences in the filler items were similar to those in the test items—involving perfective or imperfective verb forms. In the English experiment, the filler target sentences were constructed slightly differently. Half of the filler items included a construction with the auxiliary *be* that described a completed event (e.g., *Grandma was successful in cracking open the nut*, *The boy was done with taking apart the wooden stool*). The other half of the fillers

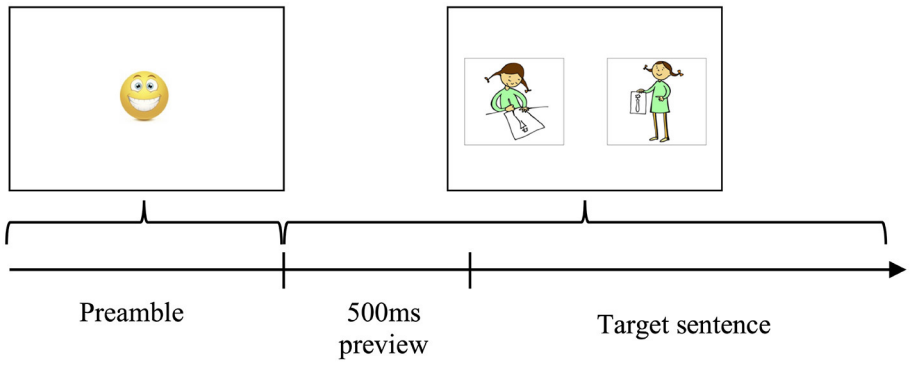

FIGURE 2
Structure of a trial.

involved a construction with a lexical verb in the past tense that described the initial or intermediate stages of an event (e.g., *The girl began to drink a glass of milk*, *Grandpa occupied himself in the strawberry patch*). The fillers were designed this way to prevent an experimental bias effect whereby the presence of the auxiliary *be* would be uniquely associated with one type of picture (recall that the imperfective test items involved a verb in the Past Progressive form which includes the auxiliary *be* and which we hypothesized would be strongly associated with the ongoing event representation).

Each list contained an equal number of filler items targeting pictures of ongoing events and pictures of completed events. Each list began with a filler item in order to accommodate the participants to the procedure.

2.3. Procedure

In the Russian and English experiments, we used an SMI RED500 eye-tracker sampling at 120 Hz to record the participants' eye-movements. The visual stimuli were presented on a 22" monitor, and the participants were seated at a distance of approx. 60–70 cm from the eye-tracker attached to the bottom of the monitor. The audio stimuli were played through external speakers located at the sides of the monitor. In the Spanish experiment, eye-movements were recorded using an EyeLink Portable Duo eye-tracker attached to a 15" laptop sampling at 500 Hz.

During the instruction phase, the participants were told that they were going to hear a series of short stories. At some point during each story two pictures would appear on the screen, and the participants' task was to choose the picture that best matched the story. They were asked to select the picture by raising the corresponding hand (left or right).

The structure of the trial is schematized in Figure 2. Each trial involved a preamble phase and a target phase. During the preamble phase the participants were shown a picture of a smiley face in the middle of the screen and heard the preamble sentence. After that the trial proceeded to the target phase where two pictures were presented side by side on the screen. In the test trials the two pictures represented two stages of the same event (ongoing and result) while in the filler trials the pictures represented different events. After a pause of 500 ms the participants heard the target sentence, and had to select one of the pictures by raising a hand. The participants' eye-movement during the trial and their offline responses were recorded. The experiment lasted approx. 6 min.

2.4. Data analysis

2.4.1. Offline responses

We coded the selection of the Ongoing Event picture in the Imperfective condition and the Completed Event picture in the perfective condition as "accurate" (1). The opposite choices in the two conditions was coded as "inaccurate" (0). We then used the package *lme4* (Bates et al., 2015) of the statistics software R version 3.6.0 to fit a mixed effects logistic regression estimating the log-odds of an accurate response with the aspectual condition (Perfective vs. Imperfective) as a fixed effect. The model included a random slope for condition by participant and by item. The predictor variable was dummy-coded with Imperfective as the baseline value. *Post-hoc* comparisons using the *emmeans* package were conducted to test whether the accuracy was significantly above chance in each aspectual condition.

2.4.2. Gaze patterns

All trials with above 50% track loss were excluded prior to the analysis, resulting in the exclusion of 7 trials in the Russian experiment, 5 trials in the Spanish experiment and 3

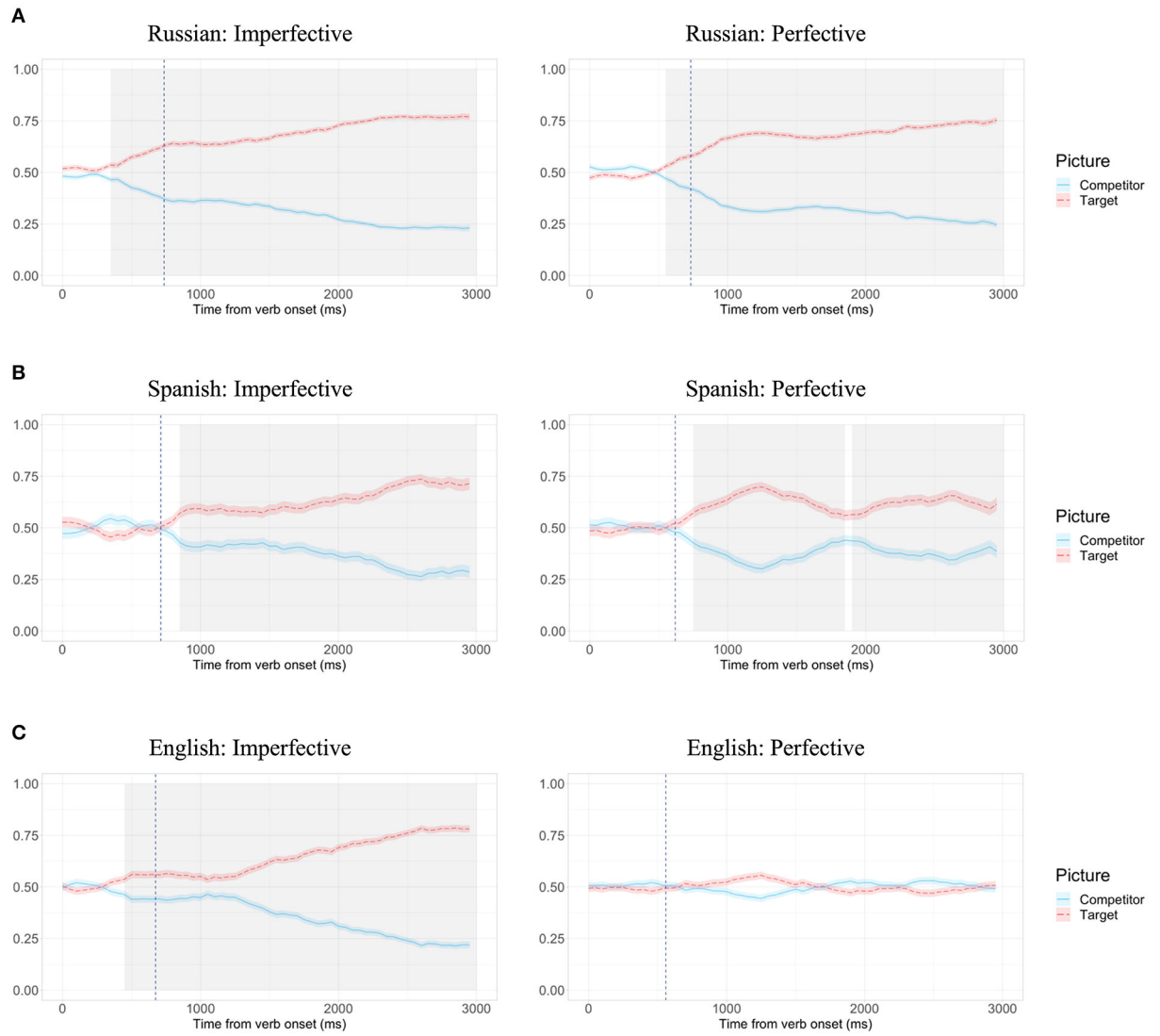

FIGURE 3
Proportions of looks to the Target and Competitor pictures in the Imperfective and Perfective conditions starting from the verb onset in Russian **(A)**, Spanish **(B)**, and English **(C)**. Shading represents significant clusters of time bins indicating above chance looks to the Target picture. Dashed vertical blue lines mark the average verb offsets.

trials in the English experiment (0.2, 0.13, and 0.65% of the data, respectively). We analyzed the proportion of looks to the Target picture separately for the two aspectual conditions: Perfective and Imperfective. For the Imperfective trials looks to the Ongoing Event picture were coded as Target (1), while looks to the Completed event picture were coded as Competitor (0). The opposite coding was employed for the Perfective trials. We calculated the proportion of looks to the target picture in 60 consecutive 50 ms time bins starting from the verb onset (see Figure 3). All looks outside of the pictures (i.e., looks to White Space) were removed (7.61% of the data in the Russian experiment, 3.45% of the data in the Spanish experiment, and 6.55% of the data in the English experiment). In the vast majority of the time bins (>95% for all three languages) this proportion was either 1 or 0. Consequently, we modeled our dependent variable as binary: we labeled every time bin where the proportion of looks was equal to or >0.5 as 1, and as 0 otherwise (Huang and Snedeker, 2020). We then performed a cluster-based permutation analysis to assess whether the probability of looks to the Target picture was significantly above chance (Maris and Oostenveld, 2007). The advantage of this method in the analysis of eye-tracking data is that it provides correction for multiple comparisons without loss of statistical power and does not inflate the rate of Type I errors due to autocorrelation (Oakes et al., 2013; Hahn et al., 2015; Huang and Snedeker, 2020; Yang et al., 2020; Minor et al., 2022).

The analysis was performed separately for each aspectual condition (Perfective and Imperfective) and involved the following steps:

1. For each time bin, we fit a mixed effects logistic model evaluating the log-odds of looks to the Target picture. The model included an intercept term, and items and participants as random intercepts. The intercept represented the difference between the log-odd of looks to the Target picture and 0, which corresponds to chance (0.5) probability.
2. We identified clusters of adjacent time bins where the Intercept p-value was below 0.1. The z-values in all the time bins in each cluster were summed up generating a sum statistic for the cluster. We chose a higher threshold for including time bins in a cluster in order to capture potential weak but long-lasting effects and avoid artificial fragmentation of clusters. This choice does not affect the overall validity of the cluster-based permutation test (Maris and Oostenveld, 2007; Hahn et al., 2015).
3. The null hypothesis was that the probability of looks to the Target picture was at chance level, i.e., that looks to the Target and Competitor pictures had equal probability. To obtain the distribution of the sum statistic under the null hypothesis we randomly permuted the picture labels (Target vs. Competitor) by participant, i.e., for each participant the picture labels were permuted in either all or none of the trials with 0.5 probability. We then performed steps 1 and 2 on the permuted dataset. The largest obtained sum statistic was stored.
4. Step 3 was repeated 1,000 times generating a distribution of the sum statistic under the null hypothesis.
5. Finally, we compared the sum statistics of the clusters identified in the original dataset to the null hypothesis distribution producing a p-value for these clusters. Clusters with $p < 0.05$ were identified as significant.[4]

3. Results

3.1. Russian

In their offline responses, Russian-speaking participants exhibited an almost universal preference for the Ongoing Event picture when they heard target sentences containing an imperfective verb (98% of the Imperfective trials, Table 1). Conversely, they exhibited an at-ceiling preference for the Completed Event picture when presented with target sentences containing a perfective verb (95% of the Perfective trials). The model predicting the log-odds of an accurate response did not reveal a significant effect of aspectual condition ($B = -1.06$, $SE = 0.93$, $Z = -1.14$, $p = 0.26$). *Post-hoc* tests revealed that accuracy was significantly above chance on both the Imperfective and Perfective conditions ($p < 0.0001$ in both cases).

TABLE 1 Accuracy of offline responses by language and aspect.

	Imperfective	Perfective
Russian	98%	95%
Spanish	97%	84%
English	96%	54%

Ongoing event picture coded as accurate response in the Imperfective condition. Completed event picture coded as accurate response in the perfective condition.

The analysis of gaze patterns revealed that in both the Imperfective and Perfective conditions the probability of looks at the Target picture was significantly above chance (Figure 3A). In the Imperfective condition this corresponded to a cluster from 350 to 3,000 ms after the verb onset (sum $z = 469.07, p < 0.001$), and in the Perfective condition—to a cluster from 550 to 3,000 ms after the verb onset (sum $z = 410.51, p < 0.001$).

3.2. Spanish

In the offline responses, Spanish-speaking participants exhibited an at-ceiling preference for the Ongoing Event picture in the Imperfective condition (97% of the imperfective trials, Table 1). In the Perfective condition participants chose the Completed Event picture in 84% of the trials. The analysis of the log-odds of an accurate response revealed a significant negative effect of aspectual condition ($B = -3.27$, $SE = 0.15$, $Z = -2.21$, $p = 0.03$), which indicates that the probability of an accurate response was significantly higher in the Imperfective condition as compared to the Perfective condition. *Post-hoc* tests revealed that accuracy was significantly above chance in both aspectual conditions ($p < 0.001$).

The pattern of looks to the Target pictured in each aspectual condition is illustrated in Figure 3B. A cluster-based permutation analysis if the gaze patterns revealed that in the Imperfective condition the probability of looks to the Target (i.e., the Ongoing Event picture) was significantly above chance corresponding to a cluster from 850 to 3,000 ms following the verb onset ($z = 165.6, p < 0.001$). In the Perfective condition the analysis identified two significant clusters (750–1,850 ms, sum $z = 99.99, p < 0.001$ and 1,900 to 3,000 ms, sum $z = 71.42, p < 0.001$) indicating that the probability of looks to the Target (i.e., the Completed Event picture) was once again significantly above chance.

4 R scripts used for the analysis of gaze patterns and offline responses are available at https://osf.io/38jz5/.

3.3. English

In the picture selection task, English-speaking participants exhibited an at-ceiling preference for the Ongoing Event picture in the Imperfective (Past Progressive) condition (96% of the Imperfective trials, Table 1). However, in the Perfective (Simple Past) condition the participants did not show a strong preference for either picture choosing the Completed Event picture in only 54% of the trials. A binomial generalized mixed model revealed a significant effect of aspectual condition ($B = -5.74$, $SE = 1.14$, $Z = -5.02$, $p < 0.001$), indicating that the proportion of accurate responses was significantly higher in the Imperfective condition as compared to the Perfective condition. *Post-hoc* tests showed that in the participants exhibited above chance accuracy in the Imperfective condition ($Z = 5.53$, $p < 0.001$), but not in the Perfective condition ($Z = 0.87$, $p = 0.38$).

Figure 3C illlustrates the proportions of looks to the Target picture for the two aspectual conditions. A cluster-based permutation analysis revealed that in the Progressive condition the probability of looks to the Target picture was significantly above chance corresponding to a cluster from 450 to 3,000 ms after the verb onset (sum $z = 283.62$, $p < 0.001$, represented by shading in Figure 3C). The analysis of the Simple Past condition, on the other hand, did not reveal any significant clusters (largest cluster from 1,050 to 1,350 ms, sum $z = 13.06$, $p = 0.2$). We were thus unable to reject the null hypothesis that the participants had no preference for the Target picture in the Perfective (Simple Past) condition.

3.4. Cross-linguistic comparison

To compare the interpretation of Perfective forms between the three languages, we analyzed the effect of language on the probability of an accurate offline response in the Perfective condition. We fit a mixed effects logistic regression predicting the log-odds of an accurate response in the Perfective condition (i.e., selection of the Completed Event picture) with language as a fixed effect. The model included random intercepts by participants and items, and a random slope for Language by item. The fixed effects variable was treatment coded with Russian taken as the baseline. The model revealed significant differences between English and Russian ($B = -4.51$, $SE = 0.52$, $Z = -8.62$, $p < 0.001$) and between Spanish and Russian ($B = -2.16$, $SE = 0.56$, $Z = -3.83$, $p < 0.001$), indicating that in the Perfective condition the Russian-speaking participants were significantly more accurate than their English-speaking and Spanish-speaking counterparts. *Post-hoc* pairwise comparisons further revealed a significant difference between English and Spanish ($B = -2.35$, $SE = 0.45$, $Z = -3.41$, $p < 0.001$) indicating that the Spanish-speaking group exhibited a significantly higher accuracy in the Perfective condition compared to the English-speaking group.

TABLE 2 Accuracy of offline responses by language and aspect for the 11 shared items.

	Imperfective	Perfective
Russian	98%	97%
Spanish	97%	87%
English	95%	50%

These cross-linguistic differences in judgements could potentially be attributed to differences in the selection of items in the three experiments. To control for this possibility we conducted the same analysis as above on a subset of the data that included only the 11 items that were shared between all three languages. The overall proportions of accurate responses in this subset were similar to those in the full dataset (Table 2). The analysis of judgements in the Perfective condition once again revealed significant differences between English and Russian ($B = -5.06$, $SE = 0.68$, $Z = -7.43$, $p < 0.001$), Spanish and Russian ($B = -2.15$, $SE = 0.66$, $Z = -3.24$, $p = 0.001$) and English and Spanish ($B = -2.92$, $SE = 0.64$, $Z = -4.59$, $p < 0.001$), thus confirming the original conclusions.

4. Discussion

The results of our study show that in all three languages (Russian, Spanish and English) the participants demonstrated a strong preference for representations of ongoing events when they heard verbs marked with imperfective aspect. In the offline picture selection task all groups exhibited an at-ceiling (above 95%) preference for the Ongoing Event pictures in the Imperfective condition (see Table 1). Similarly, the analysis of gaze patterns revealed an above-chance preference for the Ongoing Event picture in the Imperfective condition in all thee languages. Visual inspection of the gaze patterns (Figure 3) suggests that this effect began during or soon after the presentation of the verb. These results confirm that the imperfective forms in all the three languages draw attention to the in-progress stage of the event.

Importantly, these results should not be taken as evidence that the imperfective forms considered in this study are fully equivalent. For instance, it is well-known that imperfective forms in languages like Russian and Spanish generally have a wider distribution than specialized progressive forms such as the English Progressive (e.g., they allow for habitual and generic readings, can occur on stative predicates, etc.). There are also important contrasts between imperfective forms in Slavic and Romance (Arregui et al., 2014). For example, the Russian Imperfective allows for a "general factual" (or "experiential") reading where imperfective verbs are used to refer to (possibly completed) events without a definite reference point in the past, which is not possible for the Spanish Imperfect (Grønn, 2004).

In order to allow for a meaningful cross-linguistic comparison, the context of the test sentences in the current study was constrained in such a way as to focus on one specific use of the aspectual forms—namely, their function in introducing events in a narrative setting and within a specific timeframe in the past. This was accomplished by prefacing each test sentence with a preamble sentence, e.g., *It was a bright sunny day*, *It was a crisp winter morning*, etc. The purpose of the preamble was to introduce a specific occasion in the past that would act as the reference frame for the interpretation of the test sentence, thus inhibiting habitual/generic and general factual readings of imperfective forms. The results of the study suggest that in this type of context, the imperfective forms in the three languages display similar processing effects.

Moving on to the perfective forms, Russian speakers exhibited an at-ceiling offline preference for representations of completed events in the Perfective condition (95%), which was confirmed by the analysis of the gaze patterns. Spanish speakers also demonstrated an above-chance preference for the Completed Event pictures when presented with sentences containing perfective verb forms, both in their offline responses and in the eye-tracking data. However, in the picture selection task this preference was not quite at ceiling (84%) and was significantly weaker than the opposite preference in the Imperfective condition (97%). Moreover, a cross-linguistic comparison of the offline responses in the Perfective condition revealed a contrast between the Russian and Spanish groups—with Spanish speakers selecting the Completed Event picture significantly less often than the Russian speakers. This contrast is in line with the hypothesis that Russian perfective predicates such as *narisovala vazu* "drew^{PF} a vase" semantically entail that the event reached completion, whereas corresponding predicates in the Preterite form in Spanish (*dibujó un florero*) only entail the existence of a final boundary, with event completion arising as a cancellable pragmatic implicature. If this is correct we may expect the emergence and strength of this implicature to be subject to a greater degree of variation—conditioned both by the lexical properties of particular verbs and individual differences between the speakers, and leading to a less uniform pattern of responses.

While all the perfective verbs used in Experiment 1 express event completion, it should be noted that not all perfective forms in Russian entail completion in this way. Depending on the choice of prefix, perfective forms can refer to other types of boundaries, e.g., temporal boundaries (*porisovala vazu* "drew^{PF} a vase for a while") and initial boundaries/event inception (*zapela pesn^{j}u* "began singing^{PF} a song," see Glovinskaja, 1982; Borik, 2006; Tatevosov, 2016). This suggests that in both Russian and Spanish perfectivity can be linked to the general notion of *event boundedness* (Chung and Timberlake, 1985). The difference is, however, that in Russian the specific type of boundedness (e.g., event completion/attainment of result, temporal boundedness, etc.) is explicitly signaled by the choice of prefix on the verb, whereas in Spanish it is left unspecified within the verb form.

Typological research suggests that Russian and Spanish are representative of two types of aspectual systems which differ e.g., in the way perfective and imperfective forms are used in the context of adverbials that delimit the duration of the event, see e.g., Examples (8) and (9) (Dahl, 1984; Bybee and Dahl, 1989; Timberlake, 2007). An interesting prospect for future research would be to test whether the type of contrast we observed between Russian and Spanish in our experiments extends to other languages with typologically similar aspectual systems.

Perhaps the most striking result of our study concerns the Perfective (Simple Past) condition in the English-language experiment. Here, the participants' preference for the Completed Event picture in the offline task was not significantly different from chance (54%), and was significantly lower than in Russian and Spanish. Similarly, the participants' gaze patterns showed equal preference for the Completed and Ongoing Event pictures. This suggests that even on telic predicates, the English Simple Past form does not encode a preferential cognitive salience for either the activity portion of an event or its result state. These results were further replicated in an online study involving 124 English-speaking participants that combined a picture selection task with webcam-based eye tracking (Vos et al., 2022a).

We believe that these results lend support to the analysis of the English Simple Past as a non-aspectual tense form (Swart, 1998), rather than as a perfective form on a par with perfectives in languages like Russian and Spanish. Furthermore, if this conclusion is correct then it points toward the need to dissociate the rules of narrative sequencing from grammatical aspect. Specifically, the pattern we observe in Examples (6) and (10) suggests that in English these rules are tied to the sortal distinction between stative and non-stative eventualities, with states requiring overlap and non-states favoring a sequential narrative interpretation (Kamp and Reyle, 1993). Progressive verbs pattern with statives which suggests that the function of the Progressive *-ing* form may be to turn non-stative predicates into (derived) statives (Vlach, 1981; Hallman, 2010; Ramchand, 2018). The English Simple Past is the tense of narrative progression on dynamic verbs, but is underspecified with respect to boundedness.

Given the outcomes of our experiment for the English Simple Past, it is a natural to ask how the English Perfect tense would align with respect to this dichotomy. In a follow up experiment we compared the Progressive with the Perfect in both past and present tense conditions (Vos et al., 2022b). The preliminary results confirm that the Perfect in English does indeed highlight the result state of a telic event in a way that the Simple Past does not. In English, the Simple Past and the Present Perfect are often described as being in competition. However, recent comparative corpus work shows that the distribution of these two forms in English is radically different (van der Klis et al., 2022). Specifically, in contrast to the Simple Past form,

the Present Perfect does not support narrative progression, is incompatible with past tense adverbial modification and prefers newly introduced events rather than presupposed ones. This contrasts with the other European languages in this study (French, Spanish, German and Dutch) which showed less of a difference between the auxiliary based Perfect and the Simple Past. Our tentative conclusion based on these facts is that the Perfect is the form that is specialized for highlighting a result state, but that it is *not* used for building narrative progression in discourse. Thus, the two features that are normally considered to be part of the profile of perfectivity are dissociated in the English tense/aspect system.

Before concluding we would like to point out a potential limitation of the current study, which concerns the selection of items in the three experiments. We followed a number of language-specific restrictions in selecting the items—e.g., in the Russian experiment we wanted to balance two types of aspectual marking (prefixal vs. suffixal), in the English experiment we needed to avoid particle verbs, etc. This resulted in different, but intersecting, sets of items for the three languages, giving rise to the possibility that cross-linguistic contrasts may be affected by the choice of items. To address this, we performed an analysis of the responses to the items shared between all three experiments (in addition to the analysis of the full dataset). As shown in Section 3.4, these data follow the same pattern as the full dataset, and the statistical analysis revealed the same cross-linguistic contrasts—suggesting that these contrasts cannot be explained by differences in item selection. Ideally, however, in order to maximize the power to detect cross-linguistic contrasts while controlling for any possible confounds related to item selection, the sets of items for the different languages should be kept as similar as possible. The effects of item selection and inter-item variability is an interesting topic for future research.

Summing up, our study revealed a uniform pattern of processing of imperfective forms across Russian, Spanish and English, but striking variation when it comes to forms that have been analyzed as "perfective." These results have implications for the theoretical analysis of tense-aspect categories, as well as for future experimental studies that rely on particular assumptions about the semantics and processing of aspectual forms.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://osf.io/38jz5/.

Ethics statement

The studies involving human participants were reviewed and approved by Norwegian Center for Research Data (NSD, https://www.nsd.no/en). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

SM, NM, and GR contributed to conception and overall design of the study. GG contributed to the design of the Spanish experiment and collected the data. SM and NM collected the data for the Russian experiment. SM, MV, and GR collected the data for the English experiment. SM performed the statistical analysis. GR and SM wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

Funding

SM, MV, and GR were funded by the Norwegian Research Council (Grant No. 275490, Modal Concepts and Compositionality project). GR was the Principal Investigator on this grant. NM was funded by the Norwegian Research Council (Grant No. 250857, Micro-variation in Multilingual Acquisition and Attrition Situations project, awarded to Marit Westergaard). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Acknowledgments

We would like to thank Sergei Tatevosov, Olga Dragoy, Anastasia Lopukhina, and Olga Eremina for their help in organizing data collection for the Russian experiment. We would also like to thank the Norwegian University of Science and Technology (NTNU) in Trondheim, and especially Dave Kush, for assistance in organizing supplementary data collection for the English part of the study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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