# Heating up or cooling up the brain: MEG evidence that phrasal verbs are lexical units

Bert Cappelle, Yury Shtyrov, Friedemann Pulvermüller

| (1) Perspectives on the **linguistic status** of verb-particle combinations | |
|---|---|
| *Assumption A:*<br>Linkage is **lexical** in nature; storage as one word<br><br>*Prediction A:*<br>**Enhanced** magnetic brain response to particles, both *up* and *down*, in congruent combinations | *Assumption B:*<br>Linkage is **syntactic** in nature; generation on the basis of a phrase-structure rule<br><br>*Prediction B:*<br>**Reduced** magnetic brain response to particles, both *up* and *down*, in congruent combinations |
| (2) Perspectives on the impact of **semantics** on the status of verb-particle combinations | |
| *Assumption A:*<br>The role of semantics is **critical**; semantically non-transparent combinations are lexically listed, but transparent ones are syntactically assembled<br><br>*Prediction A:*<br>**Enhanced** magnetic brain response to particles, both *up* and *down*, in congruent combinations, used in a figurative (metaphorical) sense, but **reduced** response to both particles in congruent combinations which are transparent. | *Assumption B:*<br>Semantics is **irrelevant**; (common) combinations are lexically listed, whether they are non-transparent or transparent<br><br>*Prediction B:*<br>**Enhanced** magnetic brain response to particles, both *up* and *down*, in congruent combinations, both in a figurative (metaphorical) sense and in their transparent spatial sense. |

Table 1. Summary of the main competing linguistic positions on the status of phrasal verbs and the role of semantics, and the associated conflicting experimental predictions about neurophysiological correlates, on the background of pre-existing Mismatch Negativity research.

| | standard stimuli | deviant stimuli | | | | | |
|---|---|---|---|---|---|---|---|
| | | critical stimuli | | filler items | | | |
| | 50% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% | 8.33% |
| block 1 | ***rise*** | ***up*** | ****down*** | *us* | *ut* | *doubt* | *douge* |
| block 2 | ***fall*** | ****up*** | ***down*** | *us* | *ut* | *doubt* | *douge* |
| block 3 | ***heat*** | ***up*** | ****down*** | *us* | *ut* | *doubt* | *douge* |
| block 4 | ***cool*** | ****up*** | ***down*** | *us* | *ut* | *doubt* | *douge* |
| *... rise us rise douge rise up rise doubt rise douge rise up rise down rise ut ...* | | | | | | | |

Table 2. Experimental design. Standard and deviant stimuli are given for each of the four experimental conditions ('blocks'). The probability with which each stimulus occurred within a block is indicated at the top of the column (in percent). At the bottom, a short example sequence containing standard and deviant stimuli is given for experimental block 1. Note that block order was counterbalanced between subjects.

| stimulus | | *up*[1] | | *down*[1] | |
|---|---|---|---|---|---|
| | word frequency | 172677 | | 80910 | |
| | | frequency of combination | NSP[2] | frequency of combination | NSP[2] |
| *rise* | 10450 | 125 | 69.27 | 1 | 1.18 |
| *fall* | 10890 | 2 | 1.06 | 207 | 234.93 |
| *heat* | 5791 | 78 | 78.00 | 2 | 4.27 |
| *cool* | 3822 | 1 | 1.52 | 90 | 291.04 |

Table 3. Word frequencies and normalised sequential probabilities (NSP) for all standard and critical deviant stimulus words and word combinations, based on the 100 million word British National Corpus (BNC), accessed via Davies's (2004) interface.

[1] Frequencies given for *up* and *down* (in isolation and in combination with the standard stimuli) are for their use as particles, since *up* and *down* were recorded with the intonation of a particle (rather than that of a preposition) vis-à-vis the preceding word.

[2] NSP values are multiplied by $10^9$ for ease of presentation and interpretation.

**Figure legends**

Fig. 1. The stimuli were presented in counterbalanced fashion, in which the particle renders the whole standard-deviant combination pair as an existing phrasal verb or as an infelicitous verb-particle combination. Additional filler items were included in order to keep the percentage of the critical combinations low (maintaining the requirements of optimum oddball paradigm for responses elicitation), and to provide competitive environment for the particles.

Fig. 2. Shown are data from the channel with maximum response amplitude in the grand-average data (MEG0242, after SS and realignment). Note the divergence (highlighted in yellow) between the responses to physically identical items presented in different contexts. This difference was maximal at ~190 ms. Note also that the dynamics shown by the MMNm (shown in (a)) is identical to that seen in oddball ERFs before the subtraction (shown in (b)). Other gradiometer recordings showed similar enhancement of the magnetic brain response to congruent verb-particle combinations, especially over temporal and parietal areas (Figures 3 and 4).

Fig. 3. RMS values were calculated from all 204 gradiometer channels. Note that event-related magnetic brain responses were larger to particles presented in congruous contexts than responses to the same items placed in infelicitous contexts. Furthermore, note the absence of significant differences between metaphorical combinations (with a non-spatial use of the particle) and transparent combinations (with a spatial use of the particle).

Fig. 4. Each local field gradient value is calculated as the RMS of two orthogonal gradiometer recordings and differences between RMS values are shown (congruent minus incongruent). Note the bilateral distribution of the effects suggesting contributions of temporal and parietal cortex.

Fig 1. Spectrograms of spoken verb-particle stimuli and illustration of experimental design.

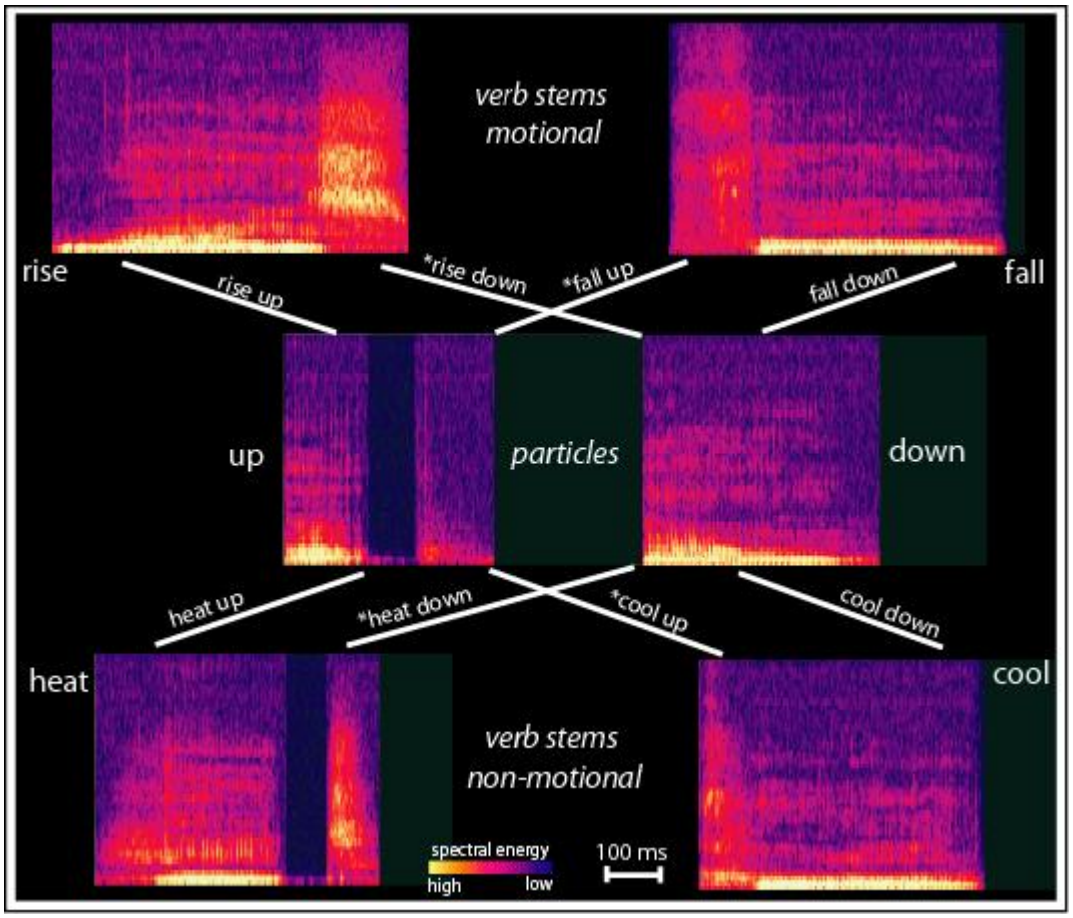
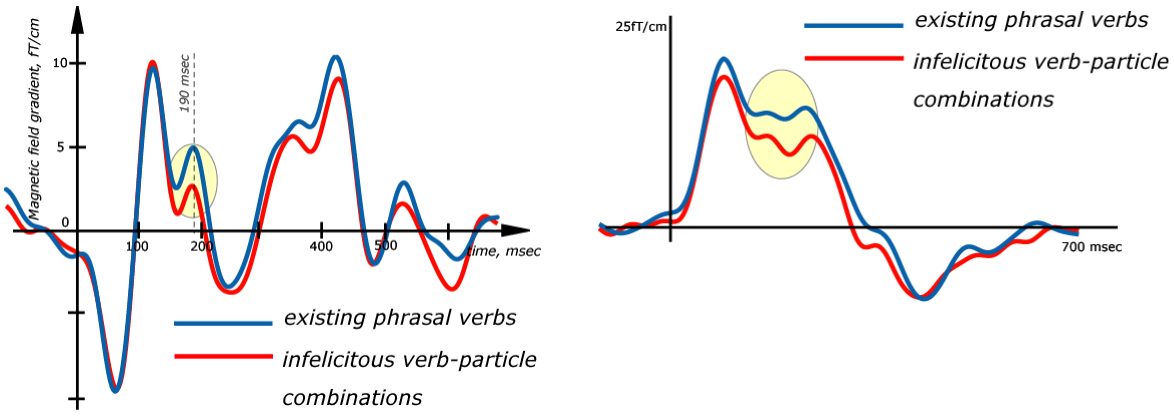


Fig. 2. (a) Magnetic mismatch negativity (MMNm, i.e. deviant response – standard response) and (b) 'oddball' (i.e. deviant response) event-related magnetic fields elicited by critical particles in context of legal and illegal verb stems.




(a) (b)

Fig 3. Mean values of RMS amplitudes (+/- standard errors of mean) produced by the same particles in existing phrasal verbs and in infelicitous contexts.

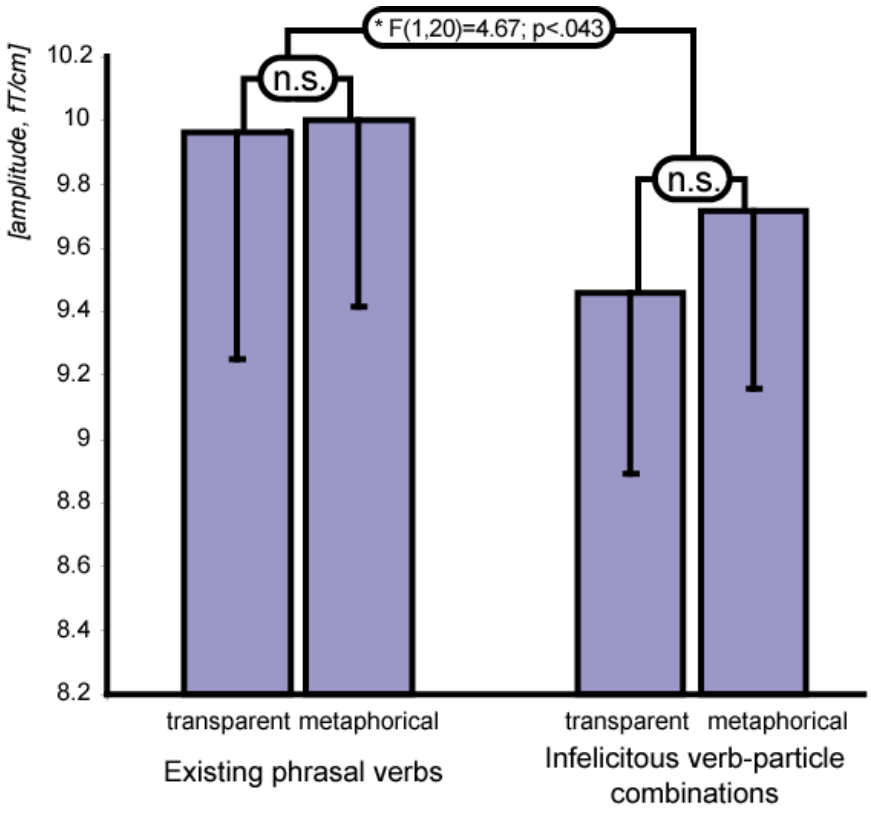


Fig. 4. Topographical maps of field gradient amplitude difference between responses to the same critical stimuli (particles) presented in felicitous and infelicitous contexts in left and right hemispheres.