**On-line Supplementary Materials**

**Appendix S1: A full list of the existing and novel binomials used in the experiment, with raw frequencies and ratio of forward to backward occurrences**

| **Phrase** | **Forward Freq** | **Forward Zipf** | **Backward Freq** | **Backward Zipf** | **Ratio** | **Forward Association** | **Backward Association** | **Repetitions****(in text)** | **Existence in Arabic**  | **Direction in Arabic**  | **Familiarity rating**  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Existing binomials** |  |
| aches and pains | 71.00 | 2.86 | 1.00 | 1.30 | 71.00 | 0.62 | 0.04 | 1.00 | Existing  | Forward  | 4.39 |
| black and white | 1119.00 | 4.05 | 57.00 | 2.76 | 19.63 | 0.58 | 0.55 | 1.00 | Existing  | **Both**  | 7.00 |
| boys and girls | 383.00 | 3.58 | 93.00 | 2.97 | 4.12 | 0.81 | 0.50 | 1.00 | Existing  | **Both**  | 6.96 |
| brother and sister | 473.00 | 3.68 | 27.00 | 2.45 | 17.52 | 0.57 | 0.63 | 1.00 | Existing  | Forward  | 6.91 |
| food and drink | 210.00 | 3.32 | 8.00 | 1.95 | 26.25 | 0.14 | 0.01 | 1.00 | Existing  | Forward  | 6.96 |
| knife and fork | 150.00 | 3.18 | 4.00 | 1.70 | 37.50 | 0.45 | 0.65 | 1.00 | Existing  | **Reverse**  | 6.70 |
| mum and dad | 516.00 | 3.71 | 11.00 | 2.08 | 46.91 | 0.70 | 0.56 | 1.00 | Existing  | **Both**  | 7.00 |
| name and address | 657.00 | 3.82 | 2.00 | 1.48 | 328.50 | 0.10 | 0.13 | 1.00 | Existing  | Forward  | 6.96 |
| son and daughter | 133.00 | 3.13 | 11.00 | 2.08 | 12.09 | 0.49 | 0.63 | 1.00 | Existing  | **Reverse**  | 6.70 |
| tea and coffee | 133.00 | 3.13 | 19.00 | 2.30 | 7.00 | 0.18 | 0.39 | 1.00 | Existing  | **Both**  | 6.78 |
| time and money | 271.00 | 3.43 | 29.00 | 2.48 | 9.34 | 0.00 | 0.00 | 1.00 | Existing  | Forward  | 6.22 |
| wind and rain | 103.00 | 3.02 | 17.00 | 2.26 | 6.06 | 0.10 | 0.00 | 1.00 | Existing  | Forward  | 5.57 |
| **Novel binomials** |  |
| bags and coats | 9.00 | 2.00 | 2.00 | 1.48 | 4.50 | 0.00 | 0.00 | 4.00 | Novel  | --- | 4.83 |
| boat and train | 3.00 | 1.60 | 4.00 | 1.70 | 0.75 | 0.02 | 0.03 | 2.00 | Novel  | --- | 4.13 |
| bottles and tins | 5.00 | 1.78 | 3.00 | 1.60 | 1.67 | 0.00 | 0.00 | 2.00 | Novel  | --- | 3.61 |
| cards and gifts | 3.00 | 1.60 | 1.00 | 1.30 | 3.00 | 0.01 | 0.00 | 2.00 | Novel  | --- | 5.70 |
| chickens and rabbits | 3.00 | 1.60 | 2.00 | 1.48 | 1.50 | 0.00 | 0.00 | 2.00 | Novel  | --- | 3.70 |
| eggs and milk | 8.00 | 1.95 | 11.00 | 2.08 | 0.73 | 0.01 | 0.01 | 4.00 | **Existing**  | **Reverse**  | 6.30 |
| farms and houses | 4.00 | 1.70 | 9.00 | 2.00 | 0.44 | 0.12 | 0.00 | 4.00 | Novel  | --- | 5.43 |
| games and music | 2.00 | 1.48 | 1.00 | 1.30 | 2.00 | 0.00 | 0.00 | 4.00 | Novel  | --- | 4.30 |
| goats and pigs | 1.00 | 1.30 | 0.00 | 1.00 | 0.00 | 0.02 | 0.00 | 2.00 | Novel  | --- | 3.09 |
| grass and leaves | 4.00 | 1.70 | 6.00 | 1.85 | 0.67 | 0.00 | 0.00 | 2.00 | Novel  | --- | 5.48 |
| kitchen and bedrooms | 6.00 | 1.85 | 3.00 | 1.60 | 2.00 | 0.01 | 0.00 | 2.00 | Novel  | --- | 5.00 |
| paint and glue | 2.00 | 1.48 | 2.00 | 1.48 | 1.00 | 0.00 | 0.02 | 2.00 | Novel  | --- | 4.26 |
| plates and glasses | 5.00 | 1.78 | 1.00 | 1.30 | 5.00 | 0.06 | 0.00 | 4.00 | **Existing**  | **Reverse**  | 5.52 |
| shelves and drawers | 2.00 | 1.48 | 1.00 | 1.30 | 2.00 | 0.01 | 0.00 | 4.00 | Novel  | --- | 5.96 |
| spoons and bowls | 1.00 | 1.30 | 1.00 | 1.30 | 1.00 | 0.00 | 0.03 | 4.00 | Novel  | --- | 4.87 |
| stone and wood | 3.00 | 1.60 | 7.00 | 1.90 | 0.43 | 0.01 | 0.02 | 2.00 | Novel  | --- | 5.00 |
| stories and jokes | 2.00 | 1.48 | 3.00 | 1.60 | 0.67 | 0.00 | 0.00 | 4.00 | Novel  | --- | 5.61 |
| tennis and football | 1.00 | 1.30 | 2.00 | 1.48 | 0.50 | 0.00 | 0.01 | 4.00 | Novel  | --- | 5.26 |
| walls and fences | 11.00 | 2.08 | 5.00 | 1.78 | 2.20 | 0.04 | 0.02 | 4.00 | Novel  | --- | 4.65 |
| wires and pipes | 3.00 | 1.60 | 3.00 | 1.60 | 1.00 | 0.00 | 0.00 | 2.00 | Novel  | --- | 4.39 |

 Zipf frequencies (scale from 1 to 7 with 7 being highest frequency), association strength (from 0.00 to 1.00), and familiarity rating (scale from 1 to 7 with 7 being highest familiarity).

**Appendix S2: Item characteristics for all existing and novel binomials**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Binomial Type | Zipf forward form | Zipf reversed form | Association strength (Forward) | Association strength (Backward) | Word 1 Length  | Word 1 Zipf | Word 3 Length  | Word 3 Zipf |
|  |
| Existing binomials (*n =* 12) | 3.41 (0.36) | 2.15 (0.50) | 0.40 (0.28) | 0.34 (0.28) | 4.25 (1.14) | 5.10 (0.55) | 5.25 (1.36) | 4.93 (0.40) |  |
|  | 2.86 - 4.05 | 1.30 - 2.97 | 0.00 - 0.81 | 0.00 - 0.65 | 3.00 - 7.00 | 4.00 - 6.24 | 3.00 - 8.00 | 4.00 - 5.56 |  |
| Novel binomials(*n =* 20) | 1.63 (0.23) | 1.56 (0.27) | 0.02 (0.03) | 0.01 (0.01) | 5.50 (1.10) | 4.75 (0.36) | 5.45 (1.23) | 4.69 (0.40) |  |
|  |  1.30 - 2.08 | 1.00 - 2.08 | 0.00 - 0.12 | 0.00 - 0.03 | 4.00 - 8.00 | 4.02 - 5.30 | 4.00 - 8.00 | 4.03 - 5.79 |  |

Mean values are provided with standard deviation in parentheses and range underneath. Frequency is expressed on the Zipf scale (Van Heuven et al., 2014) from 1 to 7; association strength (Edinburgh Associative Thesaurus, Kiss et al., 1973) is measured on a scale from 0.00 to 1.00; word length is measured in characters.

**Appendix S3: Procedures of operationalizing congruency**

Operationalizing congruency was done in two steps. In the first step, we presented the 32 target items to five proficient Arabic-English speakers and asked them to decide if each English target existed in Arabic, that is, whether the direct translation of the English binomial yielded a common expression in Arabic. Only items with an 'existence' decision that was shared by at least three of the five judges were classified as 'existing in both languages' or 'existing only in one language', respectively. All 'existing' binomials were also 'existing' in Arabic. However, for the 'novel' category, there was a mismatch whereby two English novel binomials were common in Arabic.

The second step for defining congruency evaluated the direction of the 'existing' binomials (forward vs. reverse). Initially, we asked the five Arabic-English bilinguals to decide on the most common direction in Arabic, but there was considerable variation in judgements. Then, we used the Arabic Corpus Tool (https://arabicorpus.byu.edu/), but it did not include occurrences of all binomials. Eventually, we decided to use Google as a corpus and searched for the literal Arabic translation of the 12 'existing' binomials in both directions such as 'boys and girls' (forward) vs. 'girls and boys' (reverse). An arbitrary, threshold of 3/1 was set for a conventionalized direction of a given binomial. It should be noted that this is a low threshold in comparison to the original threshold set by Conklin and Carrol (2021). The small difference between the 'forward' and 'reverse' direction for the translated binomials in Arabic seems to suggest that, unlike English, Arabic is more tolerant when it comes to binomial configurations. While the average 'forward-reverse' ratio for the six binomials that existed in both languages was 76:1 (*SD* = 125.71) for the English version according to the BNC frequency, it was only 10:1 (*SD* = 13.88) for their Arabic equivalents based on Google frequency. At the end, we found that of the 12 existing binomials, six had the same direction in both Arabic and English while the other six either had no preferred order or had the opposite order.

**Appendix S4: Pairwise comparisons between forward and reversed forms for existing and novel binomials for whole phrase RTs, word 1 and word 3**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | *Estimate* | *SE* | *t* | *lower* | *upper* | *p* |  | *Cohen's d* |
| **First-pass RT** | Whole phrase | Existing binomials | Forward - reversed | −0.01 | 0.04 | −0.24 | −0.08 | 0.06 | .81 |  | −0.01 |
|  |  | Novel binomials | Forward - reversed | 0.15 | 0.03 | 5.11 | 0.09 | 0.21 | < .001 | \*\*\* | 0.25 |
|  | Word 1 | Existing binomials | Forward - reversed | 0.03 | 0.03 | 0.99 | -0.03 | 0.08 | .32 |  | 0.06 |
|  |  | Novel binomials\* | Forward - reversed | 0.09 | 0.02 | 4.31 | 0.05 | 0.14 | < .001 | \*\*\* | 0.21 |
|  | Word 3 | Existing binomials | Forward - reversed | −0.02 | 0.03 | −0.84 | −0.07 | 0.03 | .40 |  | -0.05 |
|  |  | Novel binomials | Forward - reversed | 0.16 | 0.02 | 8.03 | 0.12 | 0.20 | < .001 | \*\*\* | 0.40 |
|  |  |  |  |  |  |  |  |  |  |  |  |
| **Total RT** | Whole phrase | Existing binomials | Forward - reversed | −0.01 | 0.03 | −0.39 | −0.06 | 0.04 | .69 |  | −0.02 |
|  |  | Novel binomials | Forward - reversed | 0.28 | 0.02 | 13.95 | 0.24 | 0.31 | < .001 | \*\*\* | 0.62 |
|  | Word 1 | Existing binomials | Forward - reversed | 0.02 | 0.03 | 0.50 | −0.05 | 0.08 | .62 |  | 0.03 |
|  |  | Novel binomials | Forward - reversed | 0.16 | 0.02 | 6.44 | 0.11 | 0.20 | < .001 | \*\*\* | 0.32 |
|  | Word 3 | Existing binomials | Forward - reversed | −0.03 | 0.03 | −1.08 | −0.09 | 0.03 | .28 |  | −0.07 |
|  |  | Novel binomials | Forward - reversed | 0.25 | 0.02 | 10.69 | 0.20 | 0.30 | < .001 | \*\*\* | 0.52 |

\* The model for first-pass RT - word 1 (Table 2) shows no main or interacting effect of direction or phrase type. Thus, the significant 'forward-reversed' difference for novel binomials should be interpreted cautiously.

 \*\*\**p* <.001

**Appendix S5: Pairwise comparisons between first, last, and reversed iterations of novel binomials for whole phrase RTs, word 1 and word 3**

|  |  |  | *Estimate* | *SE* | *t* | *lower* | *upper* | *P* |  | *Cohen's d* |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **First-pass RT** | Whole phrase | Iteration (first) - Iteration (last) | 0.06 | 0.03 | 1.87 | 0.00 | 0.11 | .06 |  | 0.09 |
|  |  | Iteration (first) - Iteration (reversed) | 0.15 | 0.03 | 4.97 | 0.09 | 0.21 | < .001 | \*\*\* | 0.24 |
|  |  | Iteration (last) - Iteration (reversed) | 0.09 | 0.03 | 3.10 | 0.03 | 0.152 | .002 | \*\* | 0.15 |
|  | Word 1 | Iteration (first) - Iteration (last) | 0.04 | 0.02 | 1.91 | 0.00 | 0.08 | .06 |  | 0.09 |
|  |  | Iteration (first) - Iteration (reversed) | 0.10 | 0.02 | 4.40 | 0.05 | 0.137 | < .001 | \*\*\* | 0.22 |
|  |  | Iteration (last) - Iteration (reversed) | 0.05 | 0.02 | 2.48 | 0.01 | 0.10 | .01 | \* | 0.13 |
|  | Word 3 | Iteration (first) - Iteration (last) | 0.10 | 0.02 | 5.06 | 0.06 | 0.14 | < .001 | \*\*\* | 0.25 |
|  |  | Iteration (first) - Iteration (reversed) | 0.16 | 0.02 | 7.94 | 0.12 | 0.20 | < .001 | \*\*\* | 0.39 |
|  |  | Iteration (last) - Iteration (reversed) | 0.06 | 0.02 | 2.93 | 0.02 | 0.10 | .003 | \*\* | 0.14 |
|  |  |  |  |  |  |  |  |  |  |  |
| **Total RT** | Whole phrase | Iteration (first) - Iteration (last) | 0.16 | 0.02 | 7.98 | 0.12 | 0.19 | < .001 | \*\*\* | 0.34 |
|  |  | Iteration (first) - Iteration (reversed) | 0.28 | 0.02 | 14.08 | 0.24 | 0.31 | < .001 | \*\*\* | 0.60 |
|  |  | Iteration (last) - Iteration (reversed) | 0.12 | 0.02 | 6.10 | 0.08 | 0.16 | < .001 | \*\*\* | 0.26 |
|  | Word 1 | Iteration (first) - Iteration (last) | 0.07 | 0.02 | 3.10 | 0.03 | 0.120 | .002 | \*\* | 0.15 |
|  |  | Iteration (first) - Iteration (reversed) | 0.16 | 0.02 | 6.55 | 0.11 | 0.20 | < .001 | \*\*\* | 0.31 |
|  |  | Iteration (last) - Iteration (reversed) | 0.08 | 0.02 | 3.44 | 0.04 | 0.131 | < .001 | \*\*\* | 0.17 |
|  | Word 3 | Iteration (first) - Iteration (last) | 0.17 | 0.02 | 7.38 | 0.12 | 0.21 | < .001 | \*\*\* | 0.35 |
|  |  | Iteration (first) - Iteration (reversed) | 0.25 | 0.02 | 10.73 | 0.20 | 0.30 | < .001 | \*\*\* | 0.52 |
|  |  | Iteration (last) - Iteration (reversed) | 0.08 | 0.02 | 3.43 | 0.03 | 0.13 | < .001 | \*\*\* | 0.17 |

\* *p* < 0.05; \*\**p* < 0.01; \*\*\**p* <.001

**References**

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