

An Asymmetrical Network Model of the Japanese EFL Learner's Mental Lexicon

Noriko Aotani*

Tokai Gakuen University

Naoki Sugino

Ritsumeikan University

Simon Fraser

Hiroshima University

Yuya Koga

Graduate School of Education, Waseda University

Kojiro Shojima

The National Center for University Entrance Examinations

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The aim of this study is to construct a model of a simple lexical network showing the strength and asymmetry of the connections between vocabulary items in the L2 mental lexicon of Japanese learners. The study focuses on eight nouns and investigates how they are networked, and whether the existing network structure formed by these nouns would be affected by the introduction of an adjective. Data in the form of perceived relatedness of the nouns collected from 17 Japanese EFL learners at different proficiency levels are analyzed using AMISESCAL (Asymmetric von Mises Scaling). AMISESCAL is a newly developed statistical model that visualizes asymmetric relations among elements on a two dimensional map. Both strength and asymmetry of the connections among vocabulary items are explicated using this model; distinctive features of the EFL learners' mental lexicon are thus obtained. The varieties of L2 network structure and the differences between individual learners are discussed.

* First/corresponding author: Noriko Aotani; second author: Naoki Sugino; third author: Simon Fraser; fourth author: Yuya Koga; fifth author: Kojiro Shojima.

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1 Introduction

Theoretical and empirical research has suggested that vocabulary items are interrelated to form a complex network in the mental lexicon (Lakoff, 1987). When new vocabulary items are acquired, they will be woven into the existing network. This process is likely to be complex for L2 vocabulary items because the influence of the already existing L1 lexical network and that of learning experience as the network develops cannot be ignored. Thus, the investigation of how learners' mental lexicons are organized, and the elucidation of the features of the L2 mental lexicon, are among the most significant research themes regarding vocabulary acquisition. However, to our knowledge, little work has been done which focuses on the influence that learners' previous experience of L1 lexicon development has on L2 vocabulary acquisition. In this respect, our previous research has shown that Japanese learners of EFL demonstrate preference for a one-way transferability; while they accept a wide range of metaphorical expansion of senses in their L1, they are reluctant to apply the same principle in L2 (Aotani, Kameyama, & Sugino, 2010; Aotani & Sugino, 2012)¹. This implies that while a large number of words are connected to one another in learners' L1 lexicon, the semantic network of words in their L2 remains much smaller.

In psycholinguistics, a number of word association norms such as USF (*The University of South Florida Association Rhyme and Word Fragment Norms*) and EAT² (*The Edinburgh Word Association Thesaurus*) have been generated based on free association experiments, which show that human word associations are asymmetric in nature. Tversky (1977) argued that similarity should not be treated as a symmetric relation which is usually represented by geometric models, which represent objects as points in some coordinate space. He contended that the assessment of similarity between objects may be described as a comparison of features rather than as the

¹ This result gave good agreement with Kellerman (1979, 1982). He mentioned that when a learner considers some items in the native language (NL) as 'language-specific', he/she would not transfer them to the target language (TL), and those he/she considers 'language-neutral' would transfer to TL, and the judgment depends on the learner's notion of the 'distance' between NL and TL. His experiments proved, even between two such close languages as Dutch and English, that Dutch learners of English tend to perceive idioms in Dutch not to be transferable to English.

² For example, in EAT, 49% of respondents produced *dog* as the response to the word *pet*, while only 1% of respondents produced *pet* as the response to the word *dog*. This difference shows that a high proportion of associations have directionality.

computation of metric distance between points. He also referred to Rosch's work (1975) regarding the prototype hypothesis, and exemplified how the perceived distance becomes smaller when the prototype is fixed at the origin rather than the variant.

In the field of corpus linguistics, a number of word association measures have been used to calculate the strength of lexical relations. There has been a particular focus on asymmetry/directionality of association (Gries, 2013; Michelbacher, Evert, & Schütze, 2007, 2011). Michelbacher et al. (2011) developed corpus-derived measures of asymmetric association to prove that not only paradigmatic relations but also syntagmatic relations have directionality, which demonstrated that asymmetry effects are characterized as human linguistic performance, and this was accurately reflected in corpus data³. Gries (2013) proposed and exemplified ΔP , which was first discussed by Ellis (2007), as a simple and advantageous directional association measure.

From the viewpoint of second language vocabulary acquisition, Imai (1993) used multi-dimensional scaling to investigate how the different senses of the word *wear*, especially metaphorically extended uses, were understood by Japanese learners, and visualized the results in a two-dimensional space based on a similarity matrix. Her visualization provided a very effective means of grasping the whole picture of a learner's mental lexicon⁴, something which we are also attempting in our research. However, the present study differs in that it focuses on the presence of asymmetric similarities between lexical items, which we believe reflects characteristics of human linguistic performance.

2 The Aim of the Present Study

We have been attempting to visualize the network properties of the mental lexicon, with a particular focus on the strength and directionality/asymmetry of links between lexical items (Sugino, Fraser, Aotani, Shojima, & Koga, 2015). Sugino et al. (2015) focused on the two uses of English adjectives, viz., predicative and attributive, and defined directionality between the adjective and noun pairs in terms of the two uses. The acceptability judgement data were used to investigate how Japanese EFL learners perceive the uses of adjectives in relation to different types of nouns, and to represent their perception in a two dimensional map by employing AMISESCAL. Based on the claim that AMISESCAL is a powerful tool in visualizing asymmetric relations among elements, we have decided to extend the scope of the present study to 1) construct a model showing the strength and

³ The rank measure and conditional measure proposed by Michelbacher et al. were later criticized by Gries (2013) because of their high error rates and computational complexity.

⁴ The term 'mental lexicon' was not used in the paper.

asymmetry of the connections between vocabulary items in a simple lexical network, and 2) to investigate and visualize the effect that the introduction of a new stimulus word has on the existing vocabulary network.

3 Procedure

3.1 Participants

Participants were 17 Japanese university students majoring in Education. Ages ranged from 18 to 22 years old. Their English proficiency level ranged from 165 to 545 on the TOEIC Test. Based on their TOEIC scores, the students were divided into two groups: a higher-proficiency group, and a lower proficiency group.

3.2 Experiment 1

Eight nouns were chosen for the experiment: *luggage*, *exercise*, *feeling*, *footstep*, *work*, *tax*, *punishment*, and *crime*⁵. A stimulus noun was chosen from among the eight nouns, and participants were instructed to judge the distance between the stimulus noun and each of the other seven nouns. Responses were scored on a five-point scale from 1 (*strongly related*) to 5 (*not related*). Another stimulus noun was then chosen, and the procedure was repeated until all eight nouns had played a role as a stimulus word.

3.3 Experiment 2

Adjective *heavy* was combined with the eight nouns from Experiment 1: *heavy luggage*, *heavy exercise*, *heavy feeling*, *heavy footstep*, *heavy work*, *heavy tax*, *heavy punishment*, and *heavy crime*. The procedures in Experiment 1 were repeated.

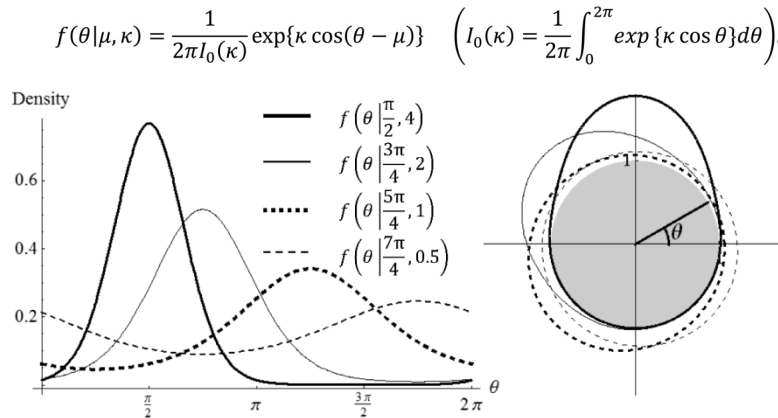
3.4 Analytical Method

The obtained data were analyzed using a new multidimensional scaling technique, AMISESCAL, which is an application of directional statistics to visualize the asymmetric structure underlying the data matrix developed by co-author of this paper, Kojiro Shojima in 2011. It uses the von Mises distribution (vMd) for its normal distribution, and the vMd can be expressed as a function of μ (the Mean Direction Parameter) and κ (the Concentration Parameter) (Shojima, 2011, 2012)⁶. For example, the various vMds in the

⁵ These eight nouns were chosen as vocabulary items that highlight different facets of the metaphorical expansion of the senses of *heavy*.

⁶ Also see <http://www.rd.dnc.ac.jp/~shojima/ams/index.htm> for details of AMISESCAL.

graph on the left of Figure 1 can be graphically displayed around a circle, as shown on the right. This is a great advantage of AMISESCAL that can enable us to visually understand the relationship between the items.



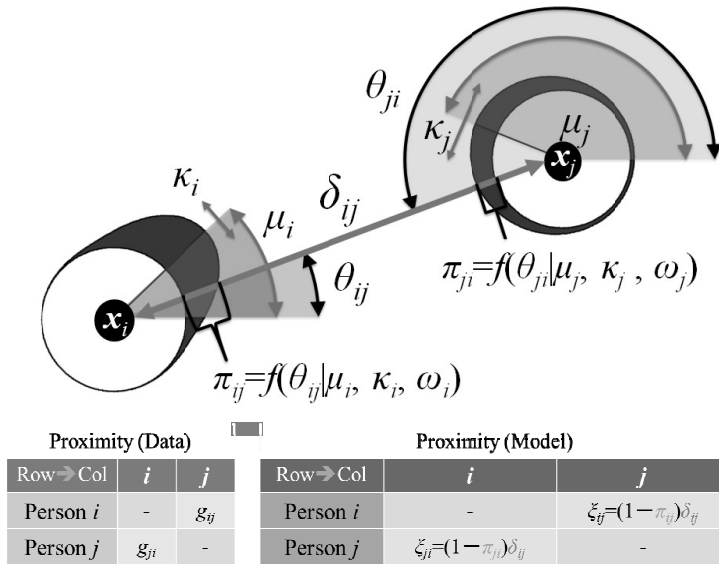
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Figure 1. Graphical representation of the von Mises distributions

Figure 2 depicts the relation between two items (x_i and x_j). The relative proximity represents the similarity between the two items, and the size and direction of vMd (π_{ij} and π_{ji}) shows the asymmetric relation.

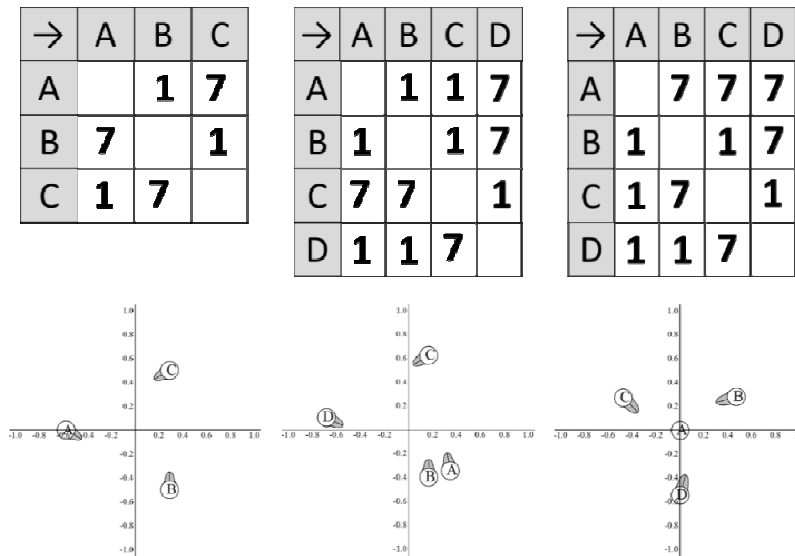
As a simple example, compare the three diagrams below representing socio-dynamics. The table on the left of Figure 3 shows that A likes B but not C, B likes C but not A, and C likes A but not B. These asymmetries are represented by the direction in which each vMd is pointing. In the middle table, both A and B like C and each other, but they don't like D. However, C doesn't like either A or B, while D likes them both. These asymmetries in relations are represented in the middle figure. Note that A and B are positioned close together.

In this study, a pair of words, $word_A$ and $word_B$, are in an asymmetric relationship if, for a participant, $word_A$ is perceived as semantically related to $word_B$ but not the other way around. In such a case, $word_A$ is represented with the vMd pointing at $word_B$, with a certain distance between the two.



<Adapted from <http://www.rd.dnc.ac.jp/~shojima/ams/index.htm>>

Figure 2. Graphical representation of asymmetry in AMISESCAL



<Adapted from <http://www.rd.dnc.ac.jp/~shojima/ams/index.htm>>

Figure 3. Basic behavior of the model

4 Results

Data obtained from both experiments were converted into 1-mode 2-way, asymmetric double bipartite proximity data as shown in Table 1, and were depicted on a two-dimensional map as shown in Figures 4,5, 6, and7.

Table 1. Example of Model Matrix of AMISESCAL

	Model Matrix							
	luggage	exercise	feeling	footstep	work	tax	punishment	crime
luggage		0.622	0.810	0.821	0.466	0.538	1.060	1.186
exercise	0.622		0.509	0.236	0.397	0.942	0.993	1.021
feeling	0.928	0.509		0.342	0.485	0.979	0.619	0.562
footstep	0.826	0.236	0.342		0.520	1.021	0.923	0.899
work	0.498	0.487	0.454	0.552		0.518	0.601	0.718
tax	0.538	0.905	0.956	0.981	0.483		0.768	0.979
punishment	0.891	0.923	0.618	0.915	0.435	0.766		0.229
crime	0.956	0.874	0.554	0.871	0.514	0.973	0.229	

The visualized model of the higher proficiency group obtained from Experiment 1 is shown in Figure 4, and the model in Figure 5 shows the result of the same group from Experiment 2. Figure 6 represents the result of the lower proficiency group from Experiment1, and their result from Experiment 2 is shown in Figure 7.

The represented two-dimensional maps depicting relations among the eight nouns show some similarity between the two groups; *work* appears in the center, which means it was perceived as a noun that is semantically connected with all other nouns (Figures 4 and 6). Asymmetry/directionality of relations between nouns was found in both groups. Differences can be observed regarding the spread of other nouns. The higher proficiency group seems to have a greater awareness of the senses of nouns than the lower proficiency group, as seen in the closeness of *punishment* and *crime* and *exercise* and *footstep* when compared to the closeness of the other nouns.

When a different stimulus word, in this case *heavy*, was added into the existing noun networks, restructuring occurred. *Heavy feeling* and *heavy footstep* in the higher proficiency group (Figure 5) and *heavy feeling* in the lower proficiency group (Figure 7) shifted to the center, showing that these items had a strong relationship with all the other items. The network structure thus was not always stable, but was restructured by the “force” of other vocabulary items in a way similar to the effect that occurs between struck billiard balls on a table.

It is also interesting to note that the vMd of *heavy exercise* pointed to *heavy work* only in the higher proficiency group (Figure 5), which suggests they could recognize the elements of [*excessive amount*] as a common concept in both *heavy exercise* and *heavy work*, and the former as more prototypical by interpreting the vMd's directionality and the hypothesis of prototypicality (Rosch, 1975; Tversky, 1977).

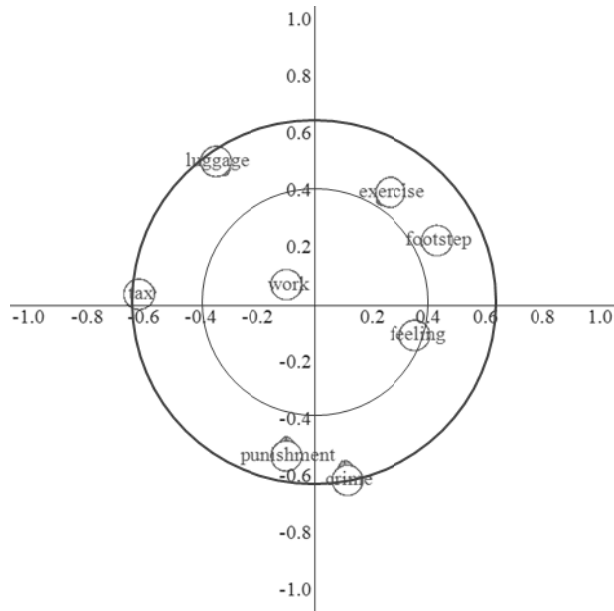


Figure 4. AMISESCAL mapping of the noun network of the higher proficiency group

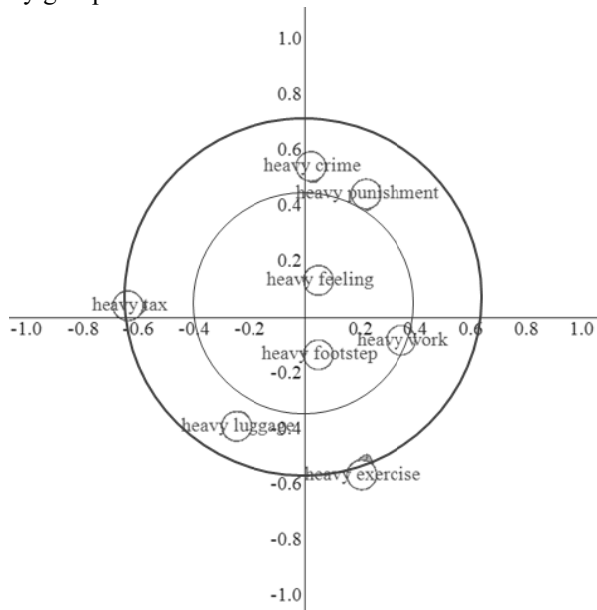


Figure 5. AMISESCAL mapping of the adjective-noun network of the higher proficiency group

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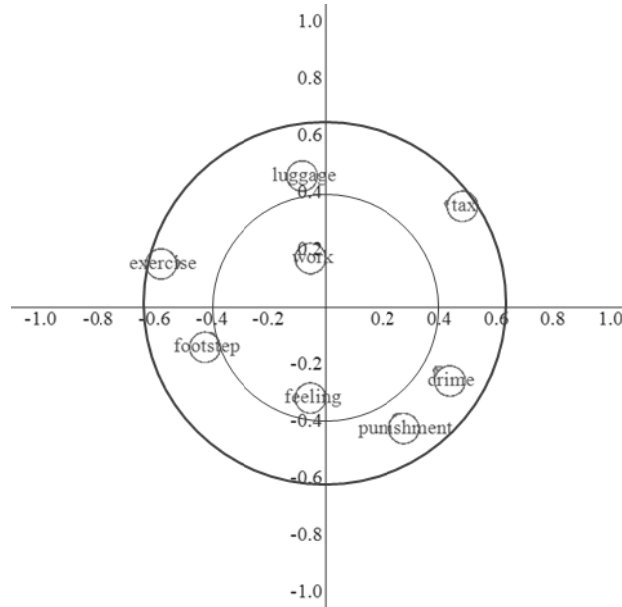


Figure 6. AMISESCAL mapping of the noun network of the lower proficiency group

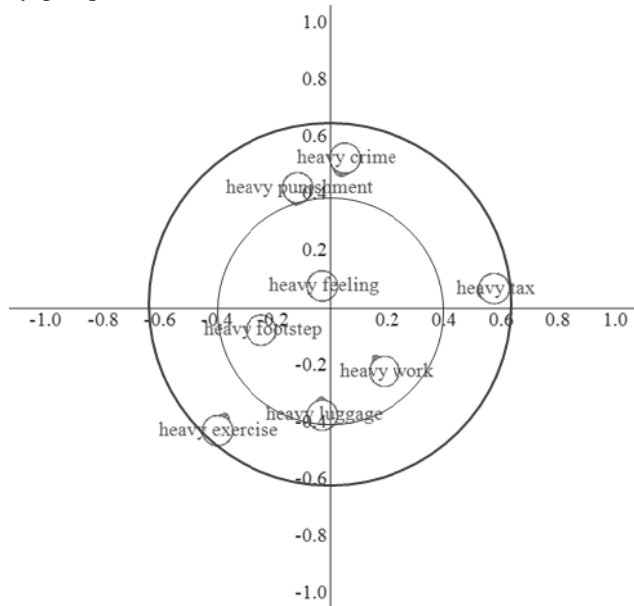


Figure 7. AMISESCAL mapping of the adjective-noun network of the lower proficiency group

One of the distinctive features of the lower proficiency group (Figure 7) is that the tendency of the vMds of items pointing to *heavy feeling* is more salient than is found in the higher proficiency group. It can be hypothesized that their criteria for judgment were affected by a causal relationship between items, such as “if we have *heavy work*, we have *heavy feeling*”, “when we have *heavy punishment*, our *feeling* must be *heavy*”. The hypothesis that the way of perceiving the relationships among vocabulary items can change from episodic (including causality) to conceptual as learners’ proficiency improves needs to be verified by collecting more data and conducting further detailed analysis.

5 Discussion

The model of the Adjective-Noun network thus obtained from this study depict show the metaphorical expansion of senses of the polysemous adjective *heavy* was perceived. The basic (literal) meaning of *heavy* is as *heavy* in *heavy luggage*, and the expansion of senses occurs from the literal meaning based on the metaphorical thinking, which would lead us to expect that *heavy luggage* must be in the center of the network among other polysemous senses of *heavy*. However, and very interestingly, this was found not to be the case in the present study⁷. Tversky (1977) implied that there is a close tie between the assessment of similarity and the interpretation of metaphors. His empirical research showed that the direction of asymmetry is determined by the relative salience of the stimuli, which are particularly noticeable in metaphors⁸. In the case of similarity judgment between *heavy exercise* and *heavy work*, for example, the difference in interpretation between “*heavy exercise* is *heavy work*,” and “*heavy work* is *heavy exercise*,” caused the asymmetrical/directional relationship between the two expressions, and it is comprehensible that this kind of deep processing was more salient in the higher proficiency group than the lower proficiency group.

In second language vocabulary acquisition, the expansion of word meanings is one of the most important and also difficult elements since it involves psychological and cognitive processes of the mind in order to reorganize the L2 mental lexicon. It is difficult for learners to consciously and visually grasp how they organize their mental lexicon. So far in this

⁷ This finding is different from Imai’s (1993), where the literal meaning of *wear* was mapped in the center of the cluster.

⁸ Tversky mentioned that similarity judgments can be regarded as extensions of similarity statements that have the form “a is like b,” which is directional because it is not equivalent in general to the converse similarity statement “b is like a.” He exemplified this with the simile “Turks fight like tigers” and not “tigers fight like Turks.”

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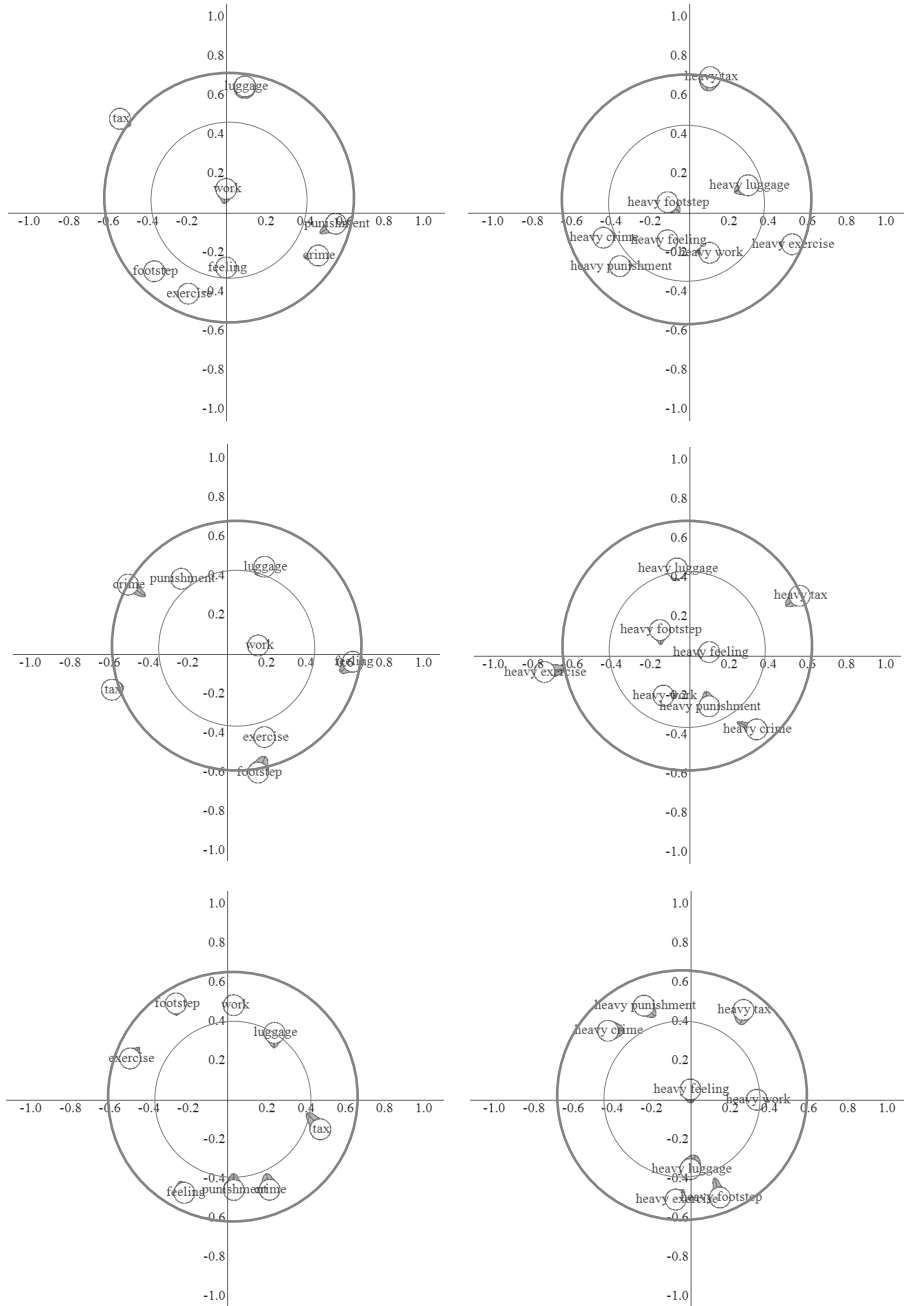


Figure 8. Individual differences represented in AMISESCAL mappings

study, we have focused on the differences between two proficiency groups. We need, also, to investigate the individual differences among learners. Figure 8 shows the individual results of some learners: the top two are from the higher proficiency group, and the bottom one from the lower proficiency group, with the Noun network on the left side and the Adjective-Noun network on the right. Further analysis will be needed to provide detailed profiles of each learner. Also, the ways in which feedback of the results can be given to learners to help improve their vocabulary knowledge should be considered.

Finally, the results of this study have shown the network structure linking vocabulary items to be, for the most part, asymmetric. AMISESCAL has been proved to be a valuable tool to visualize the directionality of the connections between elements, which might be a key to understanding the network structure of the mental lexicon.

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Noriko Aotani
Tokai Gakuen University
2-901 Nakahira, Tenpaku-ku, Nagoya, Aichi, 468-8514, Japan.
Phone: +81-52-801-1201
E-mail: aotani@tokaigakuen-u.ac.jp

Naoki Sugino
Ritsumeikan University
1-1-1 Nojihigashi, Kusatsu, Shiga, 525-8577, Japan
Phone: +81-77-561-2617
E-mail: gwisno@is.ritsumei.ac.jp

Simon Fraser
Hiroshima University
1-3-2 Kagamiyama, Higashi-Hiroshima, Hiroshima, 739-8511, Japan
Phone: +81-82-422-7111
E-mail: fraser@hiroshima-u.ac.jp

Yuya Koga
Graduate School of Education, Waseda University
1-6-1 Nishi-Waseda, Shinjuku-ku, Tokyo, 169-8050, Japan

Noriko Aotani, Naoki Sugino, Simon Fraser,
Yuya Koga and Kojiro Shojima

Phone: +81-3-3203-4141
E-mail: yuyakoga@ruri.waseda.jp

KojiroShojima
The National Center for University Entrance Examinations
2-19-23 Komaba, Meguro-ku, Tokyo, 153-8501, Japan
Phone: +81-3-3468-3311
E-mail: shojima@rd.dnc.ac.jp

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