

Betweenness Centrality and the Interdisciplinarity of *Cognitive Science*

Loet Leydesdorff,^a Robert L. Goldstone,^b and Thomas Schank^c

^a Amsterdam School of Communications Research (ASCoR), University of Amsterdam, Amsterdam, The Netherlands; loet@leydesdorff.net.

^b Department of Psychological and Brain Sciences, Indiana University, USA; rgoldstone@indiana.edu.

^c University Karlsruhe, Faculty of Informatics, ITI Wagner, Box 6980, 76128 Karlsruhe, Germany; schank@ira.uka.de

In a previous communication, Goldstone & Leydesdorff (2006) discussed the import and export of the journal *Cognitive Science* in terms of aggregated journal-to-journal citations. The main conclusion of the analysis was that the journal functions as an important intermediary between different disciplinary groups of journals that would be less directly connected if *Cognitive Science* did not exist. This bridging function is indicated by the journal's betweenness centrality^[1] in the citation impact environment of the journal, that is, the network of journals in which *Cognitive Science* is cited in a specific year. However, the analysis was based on the most recent (2004) data available at that time.^[2] Although we also compared the 2004 citation patterns with those of one previous year (1988), two snapshots cannot provide sufficient information to discern trends in the organization of cognitive science among intellectually neighboring fields.

In this brief communication, we extend our previous analysis with a dynamic perspective on betweenness centrality and the interdisciplinarity of *Cognitive Science* for the period 1994-2006. Our data are, as before, extracted from the *Journal Citations Reports* of both the *Science Citation Index* and *Social Science Citation Index*. The extension of comparing representations for different moments in time (comparative statics) to a dynamic analysis is not trivial. The differences between consecutive years do not necessarily indicate development, but include also differences in the error terms (Leydesdorff, 1991). Most techniques for dynamic visualizations are based on smoothing the transitions by linear interpolation between static representations in order to optimize the conservation of a mental map (Moody *et al.*, 2005; De Nooy *et al.*, 2005). Recently, Baur & Schank (2008) developed an MDS-based algorithm to animate time series of network data dynamically by optimizing the stress both within each year and over consecutive years, that is, by optimizing in three dimensions of the data (Gansner *et al.*, 2004). The algorithm was implemented as a tool for the generation of animations in *Visone* (Leydesdorff & Schank, 2008).^[3]

We used the same techniques as in Goldstone and Leydesdorff (2006) for each year respectively, except that the isolates after normalization (cosine ≥ 0.2) were removed for the purpose of keeping the animation readable. [The resulting animation can be seen here](#). The animation shows that the betweenness centrality of the journal (in blue) in its citation impact environment (in red) remains high over the various years, but it also shows that its relation with computer-science journals was specific for 2004. In all years under study, the journal provided an important interface between the fields of cognitive psychology and education research (e.g., the journal *Instruction and Cognition*). Over the years, other groups are linked to this core structure of cognitive psychology and education research, but these links have not been incorporated in the core set of the journal's enduring environment. Some of the fields that are relatively cohesive themselves, in that they show relatively large within-field connectivity, but are only transiently connected to Cognitive Science include: social psychology (1998), business (1995), human-computer interaction (1996), linguistics (1996-1998, and 2002), decision science (2000, 2003, and 2005).

In summary, *Cognitive Science* continues to play an important role in transmitting new insights from cognitive psychology to neighboring disciplines, but the fields of the journals in which articles from the journals are cited vary (Collins, 1977; Shunn *et al.*, 1998; Von Eckhardt, 2001). There were no structural stabilizations in these external relationships except with education research. *Cognitive Science* belongs to a group of journals in

experimental psychology, but with the specific function at the margin of the specialty of being read and cited by scholars in other relevant disciplines.

References

- Baur, M., & Schank, T., 2008. Dynamic Graph Drawing in Visone. Technical University Karlsruhe, Karlsruhe. Available at <http://i11www.ilkd.uni-karlsruhe.de/people/schank/publications/bs-dgdv-08.pdf> (Retrieved on June 20, 2008).
- Collins, A. (1977). Why cognitive science. *Cognitive Science*, 1, 1-2.
- De Nooy, W., Mrvar, A., & Batagelj, V. (2005). *Exploratory Social Network Analysis with Pajek*. New York: Cambridge University Press.
- Freeman, L. C. (1977). A Set of Measures of Centrality Based on Betweenness. *Sociometry*, 40(1), 35-41.
- Gansner, E. R., Koren, Y., & North, S. (2005). Graph Drawing by Stress Majorization. In J. Pach (Ed.), *Graph Drawing, Lecture Notes in Computer Science*, Vol. 3383, pp. 239-250, Springer.
- Goldstone, R., & Leydesdorff, L. (2006). The Import and Export of *Cognitive Science*. *Cognitive Science*, 30(6), 983-993.
- Leydesdorff, L. (1991). The Static and Dynamic Analysis of Network Data Using Information Theory. *Social Networks*, 13, 301-345.
- Leydesdorff, L. (2007). Visualization of the Citation Impact Environments of Scientific Journals: An online mapping exercise. *Journal of the American Society of Information Science and Technology*, 58(1), 207-222.
- Leydesdorff, L., & Schank, T. (2008). Dynamic Animations of Journal Maps: Indicators of Structural Change and Interdisciplinary Developments. *Journal of the American Society for Information Science and Technology* (In print; DOI: 10.1002/asi.20891).
- Moody, J., McFarland, D., & Bender-deMoll, S. (2005). Dynamic Network Visualization. *American Journal of Sociology*, 110(4), 1206-1241.
- Schunn, C., Crowley, K., & Okada, T. (1998). The growth of multidisciplinary in the Cognitive Science Society. *Cognitive Science*, 22, 107-130.
- Von Eckardt, B. (2001). Multidisciplinarity and cognitive science. *Cognitive Science*, 25, 453-470.

[1] The betweenness centrality of a vertex in a network is the proportion of shortest paths between pairs of other vertices that include this vertex (Freeman, 1977).

[2] A similar analysis was pursued by Leydesdorff (2007) for the journal *Social Networks*.

[3] *Visone* is a software package for the visualization of network data and is freely available at <http://visone.info/>.
