Teorie & Modelli, n.s., XII, 1-2, 2007 (53-62)

On the activation of information integration rules

Angela Lafratta[*] (Padua)

Information integration rules such as addition, multiplication, and averaging are practiced constantly (Anderson, 1981, 1991, 1996). These rules must thus be held in memory. It has been found that, when we encounter a new situation in which some integration of information is required for a response, we activate spontaneously one integration rule from memory. The spontaneous choice of this rule is presumably determined by our hypotheses about the new situation. It has also been found that, after we have activated a spontaneous rule from memory, training with feedback can activate a nonspontaneous rule from memory causing this new rule to supersede the previous spontaneous rule (Chasseigne, Lafon, & Mullet, 2002)[1].

For example, Chasseigne et al. (2002) had participants rate the risk of esophagus cancer (hereafter called risk) for each of different amounts of consumed tobacco and alcohol. Factorial graphs of rated risk, plotted as a function of amount of tobacco for each amount of alcohol, converged as amount of tobacco increased. This convergence is consistent with many findings of unequal-weight averaging processes, with greater weights for more extreme stimulus levels. This interpretation, accordingly, will be adopted here. Thus, participants used an unequal-weight averaging rule spontaneously. Later, the same participants rated the risk for other combinations of amounts of tobacco and alcohol. They were told after each rating what the "real" risk was. This risk was proportional to the product of the amount of consumed tobacco by the amount of consumed alcohol. After the

[*] Department of General Psychology, University of Padua.

[1] The learning of rules that define relations between variables is called rule learning (Scandura, 1969). Learned rules have been reported which regard the relation between discrete variables (Endress, Scholl, & Mehler, 2005; Macus, Vijayan, Bandi Rao, & Vishton, 1999), between a discrete and a continuous variable (Ashby & Gott, 1988; Zeithamova & Maddox, 2006), between two continuous variables (Koh & Meyer, 1991; McDaniel & Busemeyer, 2005), or between three continuous variables (Chasseigne et al., 2002; Norman, 1974a, 1974b). Information integration rules specify relations between three or more continuous variables. The activation from memory of integration rules through training with feedback has also been called rule learning (Chasseigne et al., 2002).

training with feedback, participants rated the risk for each of the original combinations of tobacco and alcohol. Now, factorial graphs diverged as the amount of consumed tobacco increased. This divergence is consistent with many findings of multiplicative processes. Thus, most plausibly, training with feedback activated a nonspontaneous multiplicative rule and made this rule supersede the previously activated spontaneous averaging rule.

The present study explored whether training with feedback is indispensable for nonspontaneous rules to supersede previously activated spontaneous rules. Experiments were made to test whether verbal instructions without training were sufficient to activate from memory a nonspontaneous integration rule capable of superseding a previously activated spontaneous rule. The first experiment, which was part of another study (Lafratta & Masin, 2006), replicated the above experiment of Chasseigne et al. (2002). The remaining experiments provided the test.

Experiment 1

Method

Participants. Ten university students with mean age of 23 years, with standard deviation of 3.1 years, participated in Experiment 1 for a payment of 5 Euros. Two of them were male.

Stimuli. The stimuli appeared in the middle of a 320 × 240-mm frontal parallel monitor screen controlled by a computer. Participants sat at about half a meter away from the screen. Each stimulus was one of the 25 different combinations of the expressions *Zero glasses of wine*, *Two glasses of wine*, *One bottle of wine*, *One and a half bottle of wine*, and *Two bottles of wine* with each of the expressions *0 cigarettes*, *20 cigarettes*, *40 cigarettes*, *60 cigarettes*, and *80 cigarettes*. Each combination of expressions was written in blue small letters within an imaginary rectangular 75 × 10-mm area, with the expression about cigarettes being below the expression about wine.

On each trial, a horizontal 76.5 × 0.5-mm yellow rating line was in the middle of the screen. Each stimulus was below the rating line with the gap between the stimulus and this line being 20 mm. A vertical 0.3 × 4-mm yellow line, called cursor, had its lower end on the rating line. At the beginning of the trial this lower end was the center of the rating line. The participant moved the cursor left or right by pressing one of two keys. The position of the cursor varied in steps of about 0.76 mm with a total of 101 different possible positions. These positions were taken to represent the integers from 0 to 100. The writings “0% risk” and “100% risk” were written in green small letters on the left and right of the rating line, respectively. The gap between the writings and the rating line was 10 mm. The screen was cleared when the participant hit a key. The rating line, cursor, writings, and subsequent stimulus appeared 1 sec after the key was hit. The stimuli were presented in random order twice consecutively.

Procedure. The procedure consisted of three sessions.

First session.—Participants were asked to rate the risk from drinking daily the amount of wine and smoking daily the amount of cigarettes mentioned in the stimulus. The experimenter read aloud these amounts for each stimulus. Participants were asked to position the cursor so that its distance from the left end of the rating line was proportional to the risk, considering that the left end of the rating line corresponded to 0% risk and the right end to 100% risk.

Second session.—The stimuli were presented as they were in the first session except that, initially, the yellow cursor was invisible. Each trial was as follows. The participant was asked to place a white vertical 0.3 × 4-mm line on the rating line in the position corresponding to the risk caused by drinking the daily amount of wine and smoking the daily amount of cigarettes reported in the stimulus. Participants did this by the mouse of the keyboard. After the participant placed the white vertical line, the experimenter pressed a key that displayed the yellow cursor in the position corresponding to the "real" risk, taken from Figure 2 in Chasseigne et al. (2002). This figure is a factorial diagram showing how risk varies with the amounts of daily intake of tobacco and daily intake of alcohol. The factorial graphs in this diagram diverge according to a multiplicative model proposed by Tuyns, Péquignot, and Jensen (1977). Participants were asked, on each trial, to place the white vertical line so that it coincided with the to-be-presented yellow cursor.

Third session.—This session was a repetition of the first session. Participants were told that the first session was being repeated and were given no further information.

Results

Figure 1 shows mean rated risk as a function of number of cigarettes smoked daily for each amount of wine drunk daily.

The left diagram shows the results from the first session when participants used an integration rule spontaneously. Graphs converge as the number of cigarettes increases showing that participants used an unequal-weight averaging rule. Wine received increasing importance as importance of cigarettes decreased. A 5 (wine) × 5 (cigarettes) analysis of variance showed that the interaction was significant [$F(16, 144) = 9.4$, $p < 0.001$].

The right diagram shows the results obtained in the third session, after participants activated a multiplicative rule. Graphs diverge as the number of cigarettes increases. This result shows that training with feedback activated a multiplicative rule which superseded the previously activated averaging rule. The interaction was significant [$F(16, 144) = 8.2$, $p < 0.001$].

The present results confirm those by Chasseigne et al. (2002). They used numerical rating rather than graphic rating as in the present case.

The results in Figure 1 are robust in that an analysis of individual data shows that, for all participants, factorial graphs converged rightward immediately after the first session when an averaging rule was used and diverged rightward after the third session when a multiplicative rule was used.

The following experiment was designed to test whether verbal instructions together with seeing a multiplicative pattern of factorial graphs would be sufficient to make participants recall a multiplicative rule.

Experiment 2

Method

Participants. Ten female university students with mean age 23 years, with standard deviation 2.6 years, took part in Experiment 2. None had participated in Experiment 1.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The procedure was the same as that for the first session of Experiment 1 except for the instructions, which were divided in two parts. In the first part, the instructions were those used in the first session of Experiment 1. In the second part, the participants were told that they would be shown how the amount of wine and number of cigarettes affect the risk according to medical studies. On the monitor screen, a Cartesian diagram was presented with the values 0%, 50%, and 100% of risk spaced equidistantly on the ordinate and with amounts of wine spaced equidistantly on the abscissa. The risk, calculated by the above multiplicative model of Tuyns et al. (1977), was shown by displaying one asterisk at a time for each increasing amount of wine. The first five asterisks referred to a person smoking 0 cigarettes, the second five asterisks referred to a person smoking 20 cigarettes, and so forth up to the five asterisks which referred to a person smoking 80 cigarettes per day. A line connected the asterisks in each block of five, forming a fan of five graphs. As graphs were progressively displayed, it was noted that increasing amounts of smoked cigarettes progressively increased the risk caused by wine, and that the increase produced by a given amount of smoked cigarettes was larger when a person was drinking larger

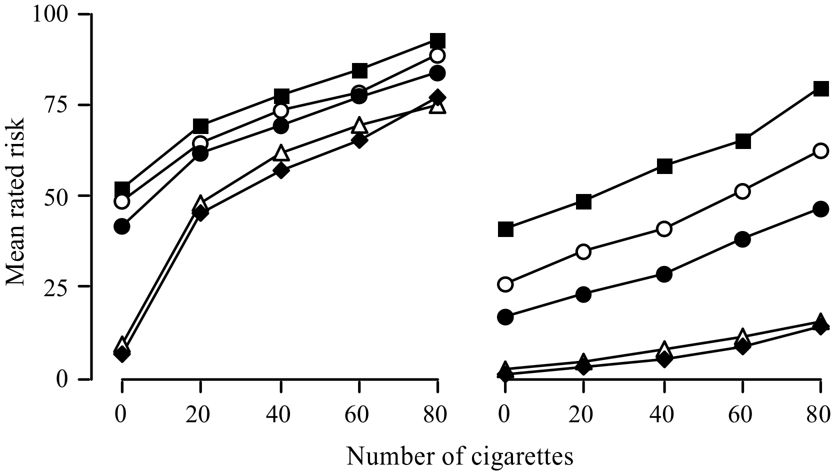

Figure 1. Mean rated risk of esophagus cancer plotted against number of cigarettes smoked daily for 0 glasses (◆), 2 glasses (△), 1 bottle (●), 1.5 bottles (○), or 2 bottles (■) of wine drunk daily, when participants used an unequal-weight averaging rule spontaneously (left) and after the same participants activated a multiplicative rule (right). The results replicate previous findings by Chasseigne et al. (2002).

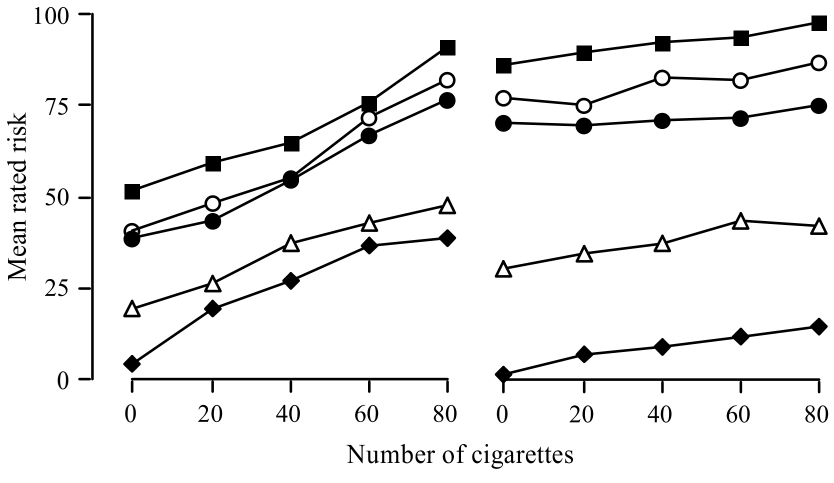

Figure 2. Mean rated risk of esophagus cancer plotted against number of cigarettes smoked daily for 0 glasses (◆), 2 glasses (△), 1 bottle (●), 1.5 bottles (○), or 2 bottles (■) of wine drunk daily, when participants were instructed to use a multiplicative rule graphically (left, Experiment 2) or verbally (right, Experiment 3).

quanties of wine than when a person was drinking smaller quantities of wine. Participants were asked to rate the risk as it had just been described.

Results

The results are reported in the left diagram in Figure 2, which shows mean rated risk as a function of number of consumed cigarettes for each amount of consumed wine. Factorial graphs are essentially parallel. The interaction was not significant [$F(4, 144) = 2.0$ with Huynh-Feldt correction].

Inspection of individual data showed that individual graphs were essentially parallel for four participants, converged rightward for three other participants, and diverged rightward for the remaining three participants. As an example, Figure 3 shows the results of one participant who produced graphs that were parallel [$F(16, 16) = 0.39$], one who produced graphs that converged rightward [$F(16, 16) = 2.9$, $p < 0.05$], and another who produced graphs that diverged rightward [$F(16, 16) = 5.7$, $p < 0.005$].

The results of Experiment 1 show that all subjects spontaneously used an unequal-weight averaging rule. The verbal-graphical instructions used in Experiment 2 should thus have had the effect of replacing this original rule with a multiplicative integration rule in three participants.

Experiment 3

The results of Experiment 2 suggest that participants had difficulty understanding the graphical explanation of a multiplicative rule. An additive rule

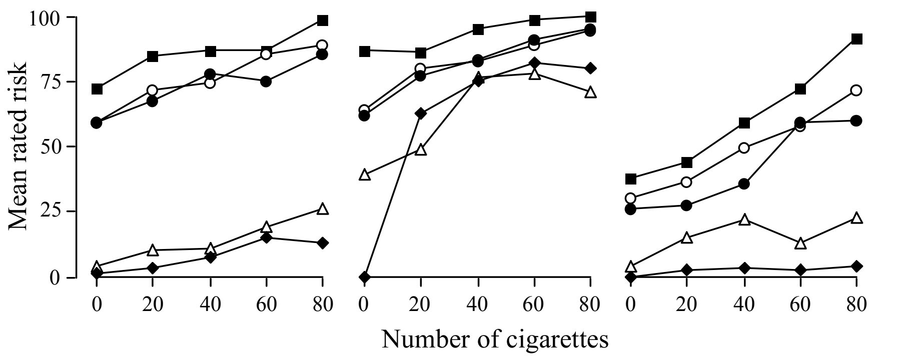

Figure 3. Examples of individual results obtained in Experiment 2. Each diagram is for a different participant.

should be easier to understand. Experiment 3 was designed to test whether an additive rule could be activated by purely verbal instructions.

Method

Participants. Five university students with mean age 22.2 years, with standard deviation of 0.8 years, participated in Experiment 3. None had participated in Experiments 1 or 2. One was male.

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. Participants were read the following three sentences: "The risk of esophagus cancer increases more the more one drinks wine. Smoking cigarettes does not cause esophagus cancer, but has only the effect of accentuating the risk of esophagus cancer caused by wine. The risk of esophagus cancer is accentuated minimally when one smokes little and is accentuated more and more the more one smokes".

Participants were asked to repeat each sentence until they understood the sentence. After this repetition, participants were asked to repeat all the three sentences in sequence. At this point, participants were read the instructions that were used in the first session of Experiment 1. Subsequently, participants were asked to repeat the three sentences once more.

Results

The results are reported in the right diagram in Figure 2 showing mean rated risk as a function of number of cigarettes for each amount of wine. Factorial graphs are essentially parallel. The interaction was not significant [$F(16, 144) = 0.8$]. Inspection of individual data showed that each participant produced essentially parallel factorial graphs. Thus one can conclude that purely verbal instructions activate an additive rule effectively.

These same instructions were used in the following experiment to test whether they can be used in place of training with feedback.

Experiment 4

Method

Participants. Ten female university students of mean age 22.5 years, with standard deviation of 1.2 years, took part in Experiment 4. None had participated in Experiments 1 to 3.

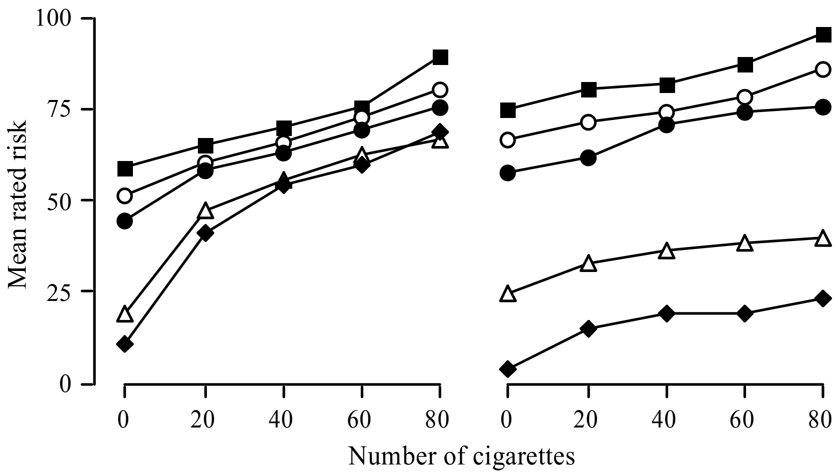

Figure 4. Mean rated risk of esophagus cancer plotted against number of cigarettes smoked daily for 0 glasses (◆), 2 glasses (△), 1 bottle (●), 1.5 bottles (○), or 2 bottles (■) of wine drunk daily, when an averaging rule was used spontaneously (left) and after an additive rule was induced by verbal instructions (right).

Stimuli. The stimuli were the same as those used in Experiment 1.

Procedure. The procedure consisted of three sessions.

First session.— The procedure for the first session was the same as that used for the first session of Experiment 1.

Second session.— The procedure for the second session was the same as that used in Experiment 3.

Third session.—The procedure for the third session was the same as that used for the third session of Experiment 1.

Results

Figure 4 shows mean rated risk as a function of number of cigarettes smoked daily for each amount of wine drunk daily. The left diagram shows the results obtained immediately after the first session. Graphs converge rightward, meaning that participants activated an averaging rule. The interaction was significant [$F(16, 144) = 10.3$, $p < 0.001$]. The right diagram shows the results obtained after the third session. Graphs are essentially parallel, meaning that participants activated an additive rule. The interaction was not significant [$F(16, 144) = 1.5$].

Factorial graphs from the first session were parallel for one participant and converged rightward for nine participants. Factorial graphs from the third session were parallel for six participants, slightly converged rightward for three participants, and diverged markedly rightward for one participant.

Conclusion

The results of Experiment 1 confirm that training with feedback effectively activates a multiplicative integration rule which takes over a previously activated averaging rule. The results of Experiments 2 and 3 show that verbal instructions of a nonspontaneous integration rule (multiplicative or additive) activate the rule in a significant number of participants. The results of Experiment 4 show that purely verbal instructions without training are sufficient to activate a nonspontaneous additive rule causing this rule to supersede a previously activated, spontaneous averaging rule.

References

Anderson, N. H. (1981). *Foundations of information integration theory*. New York: Academic Press.

Anderson, N. H. (1991). *Contributions to information integration theory*. Hillsdale, NJ: Erlbaum.

Anderson, N. H. (1996). *A functional theory of cognition*. Mahwah, NJ: Erlbaum.

Ashby, F. G., & Gott, R. (1988). Decision rules in the perception and categorization of multidimensional stimuli. *Journal of Experimental Psychology: Learning, memory, and Cognition*, *14*, 33-53.

Chasseigne, G., Lafon, P., & Mullet, E. (2002). Aging and rule learning: the case of the multiplicative law. *American Journal of Psychology*, *115*, 315-330.

Endress, A. D., Scholl, B. J., & Mehler, J. (2005). The role of salience in the extraction of algebraic rules. *Journal of Experimental Psychology: General*, *134*, 406-419.

Koh, K., & Meyer, D. E. (1991). Function learning: Induction of continuous stimulus-response relations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *17*, 811-836.

Lafratta, A., & Masin, S. C. (2006). Study of the ability to use information integration rules. *Twelfth Annual Meeting of the Cognitive Science Association for Interdisciplinary Learning*, Hood River, OR, August 10-14, 2006.

Marcus, G. F., Vijayan, S., Bandi Rao, S., & Vishton, P. M. (1999). Rule learning by seven-month-old infants. *Science*, *283*, 77-80.

McDaniel, M. A., & Busemeyer, J. R. (2005). The conceptual basis of function learning and extrapolation: Comparison of rule-based and associative-based models. *Psychonomic Bulletin & Review*, *12*, 24-42.

Norman, K. L. (1974a). Dynamic processes in stimulus integration theory: Effects of feedback on averaging of motor movements. *Journal of Experimental Psychology*, *102*, 399-408.
Norman, K. L. (1974b). Rule learning in a stimulus integration task. *Journal of Experimental Psychology*, *103*, 941-947.
Scandura, J. M. (1969). New directions for theory and research on rule learning. II. Empirical research. *Acta Psychologica*, *29*, 101-133.
Tuyns, A. J., Péquignot, O. M., & Jensen, G. (1977). Le cancer de l'oesophage en Ille-et-Vilaine en fonction des niveaux de consommation d'alcool et de tabac: Des risques qui se multiplient. *Bulletin du Cancer*, *64*, 45-60.
Zeithamova, D., & Maddox, W. T. (2006). Dual-task interference in perceptual category learning. *Memory and Cognition*, *34*, 387-398.

Abstract

Studies show that training with feedback activates nonspontaneous integration rules capable of superseding previously activated spontaneous rules. The present study explored whether verbal instructions without training are sufficient to activate nonspontaneous information integration rules capable of superseding previously activated spontaneous rules. The results show that graphical instructions can activate a multiplicative rule in some participants and that verbal instructions without training are sufficient to activate an additive rule capable of superseding a previous rule activated spontaneously.

Riassunto

Studi mostrano che l'addestramento con feedback attiva regole di integrazione non spontanee capaci di sostituirsi a regole di integrazioni spontanee precedentemente attive. Il presente studio ha indagato se istruzioni verbali senza addestramento sono sufficienti ad attivare regole di integrazione non spontanee capaci di sostituirsi a regole di integrazione spontanee precedenti. I risultati mostrano che istruzioni grafiche possono attivare una regola moltiplicativa in alcuni partecipanti e che istruzioni verbali senza addestramento sono sufficienti ad attivare una regola additiva capace di sostituirsi ad una regola spontanea attivata in precedenza.

Aknowledgment. I wish to thank Prof. Norman Anderson for useful comments.

Address. Angela Lafratta, Dipartimento di Psicologia Generale, Università di Padova, via Venezia 8, I-35131 Padova (lafratta@psy.unipd.it).