VU Research Portal

Effects of contrasting category, conjoint frequency and typicality on categorization.

Das-Smaal, E.A.; de Swart, J.H.

published in

Acta Psychologica

1986

DOI (link to publisher)

[10.1016/0001-6918\(86\)90003-X](https://doi.org/10.1016/0001-6918(86)90003-X)

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Das-Smaal, E. A., & de Swart, J. H. (1986). Effects of contrasting category, conjoint frequency and typicality on categorization. *Acta Psychologica*, 62, 15-40. [https://doi.org/10.1016/0001-6918\(86\)90003-X](https://doi.org/10.1016/0001-6918(86)90003-X)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

EFFECTS OF CONTRASTING CATEGORY, CONJOINT FREQUENCY AND TYPICALITY ON CATEGORIZATION

E.A. DAS-SMAAL * and J.H. DE SWART

Free University, Amsterdam, The Netherlands

Accepted August 1985

Two experiments were conducted to investigate whether (a) experience with a contrasting category, (b) conjoint frequency of dimensional values, (c) range of typicality of values, and (d) type of information administered during learning influenced subsequent test performance. Each experiment began with an observational category learning task, employing faces as stimuli. This was followed by a classification test task and by pairwise comparisons of faces. Influence of a contrasting category was studied in experiment 1 by varying frequency of values of the contrasting category, and in experiment 2 by either including or not including a contrasting category in the learning task. Results indicated that (a) categorization is influenced by experience with a contrasting category, (b) conjoint frequency enhances the importance of values to a category, (c) broad typicality range experience reduces typicality differences among exemplars of a category, whereas small range experience diminishes differences in a contrasting category, and (d) information on representativeness of exemplars does not facilitate subsequent test performance. The implications of the results for categorization models are discussed.

Various models have been proposed as to the basis of categorization, several of which appear to be viable. One class of models, prototype-distance models (e.g., Reed 1972), hold that a central representation (prototype) is abstracted from the experienced exemplars of a category; classification is based on distance from this prototype. Another class of models, feature frequency models (e.g., Neumann 1974), assume that frequency of dimensional values is encoded; classification is based on these frequency measures. Das-Smaal and De Swart (1984) argued that the two types of model account for different aspects of variation in the same category. They demonstrated effects of category variation resulting from two sources. Classification depended on whether or not

* Requests for reprints should be sent to: E.A. Das-Smaal, Vakgroep Functieleer en Method-
enleer, Free University, De Boelelaan 1115, 1007 MC Amsterdam BTV, The Netherlands.

relevant features (a) occurred frequently in a category and rarely in others, and (b) were represented by typical variants (e.g., a typical exemplar of a slender nose). The present study examines both forms of category variation further.

Frequency

Two frequency issues emerged from the Das-Smaal and De Swart (1984) study: frequency of occurrence of dimensional values in a contrasting category, and conjoint frequency of values.

Contrasting category

Das-Smaal and De Swart (1984) found that exemplars which were categorized best were the ones with values that occurred frequently in the focal but rarely in the contrasting category.

Das-Smaal and De Swart investigated the effect of occurrence versus non-occurrence of values in the contrasting category. The present experiment aimed to replicate these results. However, this time frequency of values in the contrasting category was varied among three values, all having the same focal frequency. It was hypothesized that focal exemplars are categorized more easily and judged more representative the lower the frequency of their values in the contrasting category.

In a second experiment, the influence of experience with a contrasting category was investigated in a second way. Instances from the contrasting category were presented either, or not at all, during learning. Different focal category representations were expected to result from these two kinds of learning experience. Influence of the contrasting category composition on subsequent test performance had to show up only when that category was experienced.

Conjoint frequency

It has been suggested (Rosch 1975; Hayes-Roth and Hayes-Roth 1977; Medin and Schaffer 1978; Das-Smaal and De Swart 1984) that conjoint frequency of values in the category of interest enhances the classification importance of those values, relative to non-redundant occurrence of the same values. However, an experiment of Kellogg

(1981), which aimed at discovering whether or not stimulus dimensions interact in category learning, failed to produce conjoint frequency effects. Kellogg concluded that dimensions are independent and that conjoint frequencies are not counted. The present study addressed the controversy about conjoint frequency by varying the co-occurrence of relevant and irrelevant values during learning. Correlation of these values was expected to increase the judged representativeness of the irrelevant value to the focal category.

Typicality

Typicality refers to the similarity of a dimensional value variant to a prototypical value (typicality of variants), e.g., the resemblance of a particular slender nose to a prototypical slender nose. Das-Smaal and De Swart (1981, 1984), showed that ease of classification increased with increasing typicality of the value variants composing an exemplar.

Das-Smaal and De Swart (1984) presented their subjects also with either a small range (typical variants only), or a broad range (both typical and atypical variants). Broad-range experience resulted in relatively large extensions of the focal category, and subjects classified atypical focal exemplars better. The typicality effect was dependent on category and range experience. In the focal category, typicality effect showed up in the small- but not in the broad-range condition. The results suggest that broad-range subjects compress the focal category in order to match the range of variants, thus reducing typicality differences. On the contrary, in the contrasting category, typicality effect occurred with broad- but not with small-range experience. The lack of effect with small-range experience was ascribed to classification by default. Small-range experience results in a small extension of the focal category. Consequently, all contrasting category members could equally easily have been rejected, because they were at quite a distance from the small focal category representation.

Unfortunately, in the experimental set-up typicality and experience with the variants were confounded. The present study aimed to investigate whether the explanations hold when this confounding factor is removed. In general, high variant typicality was expected to facilitate classification performance. However, in the focal category, the typicality effect was expected to be stronger with small- than with broad-range

experience, whereas in the contrasting category the opposite was predicted. In support of a categorization by default explanation, a smaller extension of the focal category was predicted, as well as faster categorization of contrasting category items with small- than with broad-range experience.

A third range condition was added to investigate whether or not in a broad category the multitude of different variants reduces the typicality effect. Subjects were presented with a limited number of different variants from the broad range, including the extremes (limited-range condition). A smaller typicality effect in the broad- than in the limited-range condition can be ascribed to the multitude of variants shown during learning.

Information on representativeness

In category learning experiments, feedback informs the subject about the category to which an instance belongs. Usually, no direct information about degree of category membership is given. Das-Smaal and De Swart (1984) investigated the effect of feedback specificity on learning and representation of categories. Specific feedback indicated not only the proper category, but also the degree of membership or representativeness (as determined by frequency of occurrence of its composite values). Categorization appeared not to be facilitated by specific feedback as compared with non-specific feedback. Two tentative explanations were given. First, the time to process the extra information in the specific feedback condition could have been too short, and/or the feedback information may have been confusing rather than useful. To rule out this possibility, in the present study subjects were allowed to determine their own processing time, and no overt classification response was required. If the shortage of time explanation is correct, the facilitating effect of information on representativeness has to show up. In addition, longer stimulus inspection times with specific than with non-specific information would then be expected.

The second explanation was that evaluation of information on representativeness is a relatively autonomous process. Kellogg et al. (1978) showed that frequency influences typicality judgments, and that these judgments are not affected by special instruction to learn which instances are better exemplars than others. They suggested that subjects

automatically create a gradient of membership, and that special instructions, therefore, serve no purpose. If the second explanation is correct, explicit presentation of information on representativeness would serve no purpose. Consequently, no difference between the effects of specific and non-specific information should occur.

Experiment 1

The purpose of this experiment was to investigate the effect of (1) frequency of values in the contrasting category, (2) typicality range of variants of dimensional values, and (3) information regarding representativeness of exemplars, on categorization.

In a learning task, subjects were taught to distinguish one family of faces from a contrasting category of all other faces. An observational paradigm was used, requiring the subjects just to look at faces and their proper classification. Blocks of learning trials were followed by short classification tests in order to trace the progress of learning. Following learning, subjects were tested on both a classification and a pairwise comparison task. Finally, subjects were asked to mention the characteristic features of the family to be learned.

Method

Stimuli

Stimuli were slides of faces from photo-FIT materials. Faces were composed from seven variants (numbered 1 to 7 from most to least typical) for each of three values of the dimensions eyes, nose and mouth (see Das-Smaal and De Swart 1984). In the learning task, 18 different hairstyles were assigned randomly but equally often to the faces. Another, average looking hairstyle, was used for the test faces.

Non-specific information slides contained a + or a -, indicating the focal or the contrasting category, respectively. Specific information slides showed +, ++, ++++, -, --, or ----, indicating that the concomitant stimulus was a less well, moderate, or good example of the focal category, or a less well, moderate, or good example of the contrasting category, respectively.

Pairwise comparison slides each contained two faces, labeled A and B.

Apparatus

Slides were projected onto a frosted-glass window in front of the subject. Information slides were projected below the stimulus slides. A response panel contained a 'slide off' and a starter button. The starter was surrounded by a half circle of six choice buttons, which were labeled + + +, + +, +, -, -- and ----. Pressing one of the choice buttons yielded a combined category and representativeness response. Another panel, for the pairwise comparison task, had two choice buttons (A and B) above the starter button. A lever was fixed at the side of each panel and could be moved forwards

or backwards. The range of this lever represented a continuum of certainty about the choice response. In the learning task, stimulus inspection times (ST) were measured from the beginning to the end of stimulus presentation. In the test tasks, response times (RT) were measured from the beginning of stimulus presentation to the subject's choice response. Choice responses, certainty estimates (CE), ST and RT were recorded automatically.

Design and procedure

Trial composition. When a red light came on, subjects had to start slide projection by pressing the starter button. Slides disappeared, either when the subject pressed the 'slide off' button, or automatically after 35 seconds. Four seconds later the red light came on again, indicating that the next trial could be started. Trials of the classification tests were composed as for the learning task trials. However, stimulus disappearance was brought about by pressing one of the six choice buttons, and subsequently the subject had to give his certainty rating. Pairwise comparison trials were similar to classification trials, using the choice buttons A and B.

Training task. Subjects were told that they had to learn to distinguish faces of one family (+) from all other faces (−), hairstyle being irrelevant. In the specific information condition, subjects were informed that the representativeness of a face for the focal family was indicated by number and kind of signs, with decreasing representativeness from +++ to ---. In the test tasks no category information was given. Learning and test blocks were announced by slides. To exercise the tasks, twelve observation trials were employed, followed by a classification task of four trials. Stimuli were arbitrarily composed Afro-Asian faces, with random category information, either specific or non-specific.

Learning task. Five blocks of 20 trials were administered. Stimuli of blocks 1 to 3 are given in table A.1 of the appendix. Blocks 4 and 5 were identical to blocks 1 and 2.

Focal category faces had characteristic values A1 and/or B1 + C1. Other faces were of the contrasting category. Assignment of the dimensions eyes, nose and mouth to A, B and C varied across subjects and was counterbalanced in three learning task problems, using each dimension once as A, B or C. Each problem had its own accessory tests.

To examine the influence of a contrasting category, the relevant dimensions A, B and C differed only with respect to the frequency distribution of their values in the contrasting category (see table 1).

Cue validities (also in table 1) were computed by dividing the focal frequency of a dimensional value by its total frequency in both categories. Total cue validities (TCV's) of faces were computed by summation of cue validities of their composing values. TCV's are given in table A.1 of the appendix. In the specific information condition, information on representativeness was determined by TCV. In the focal category, a high (H) TCV group consisted of exemplars with values A1, B1 and/or C1. Medium (M) TCV exemplars had A1 and/or C1. Low (L) TCV exemplars had B1 and C1. In

Table 1

Frequency of occurrence and cue validity of dimensional values. Values 1 are characteristic of the focal category.

	Dimension								
	A			B			C		
	Value			Value			Value		
	1	2	3	1	2	3	1	2	3
Frequency in category									
+	35	8	7	35	8	7	35	8	7
-	0	25	25	10	20	20	25	13	12
Cue validity	1.00	0.24	0.22	0.78	0.29	0.26	0.58	0.38	0.37

the contrasting category, group L had B1, M had C1, and H had none of the characteristic focal values. L, M and H groups of focal and contrasting category were indicated by one, two and three plus or minus signs, respectively.

Typicality was varied with seven variants for each dimensional value. Table A.1 of the appendix shows that in the focal category variants 1 to 4, 1 to 7, and 1, 4 and 7 were employed in the small-, broad-, and limited-range experience condition, respectively. In the contrasting category, variants 1 and 2, 1 to 4, and 1 and 4 were presented in these conditions, respectively. Variants were chosen randomly, and for any condition were presented equally often.

Tests during learning. In five short classification tests TCV and typicality were varied. Each test had four focal exemplars: two sets of one H and one L TCV-face. One set had variants 1, the other variants 4. Each test had also two contrasting category items: of H and L TCV, both with variants 1. The different values possible within these constraints were divided over the tests. Tests 4 and 5 were a repetition of tests 1 and 2, respectively.

Classification task. 36 faces were given. The first was meant to habituate. The next 16 faces differed in both TCV and variant typicality. Two sets of five focal exemplars, and two sets of three contrasting category items were employed. Focal exemplars were two H TCV-faces (one including and one without value C1), two M TCV-faces (also including and without C1), and one L face. Contrasting category items were the H, M and L TCV-faces of the contrasting category. One set of focal exemplars was composed of variants 1, the other set of variants 4. One set of contrasting category items had variants 5, the other variants 7. Order of presentation of the 16 faces was randomized.

Subsequently, 12 faces were presented, ranging from highly typical of the focal category to highly typical of the contrasting category, and vice versa. Successively were shown three highest TCV faces, composed of variants 1, 4 and 7, respectively, and three lowest TCV faces, with variants 7, 5 and 1, respectively, and such faces in reverse order.

Three lowest TCV faces had either dimensional values 2, or 3. Half of the subjects saw value-2 faces first, the other half saw value-3 faces first.

The last seven faces of the classification task lacked either one or two of the three relevant dimensions. Omitted values were replaced by a black rectangle. The first face was to accustom the subjects to the omission. From the next three faces, dimension A, B or C was omitted. Values that were present were both characteristic of the focal category. The last three faces each lacked two dimensions and had the characteristic value A1, or B1, or C1 only. The order of both sets of three faces varied between subjects and was counterbalanced.

Pairwise comparisons. Subjects were asked to choose the better example of the focal category in each pair. Ten pairwise combinations of five focal category faces of different TVC were given, in random order. The faces had values 111, 113, 121, 133 and 211 on dimension A, B and C, respectively. These trials were followed by three comparisons of faces that had two dimensions covered, showing either A1, or B1 or C1 only. The order of these trials varied between subjects and was counterbalanced. All values were represented by highly typical variants (variants 1). The task was preceded by a training task of five pairs not used in the test task.

Characteristic feature description. Finally, subjects were asked to describe the characteristic features of the focal family, and to give their order of importance to classification.

Variables. Between-subjects variables were typicality range, type of information, and learning task problem. Within-subject variables were learning phase, TCV, category, typicality of variants, and omission of one or two dimensions. Dependent variables were ST in the learning task, CE, RT and the combined category and typicality response (TY) in the classification tasks, and representativeness choice with pairwise comparisons. TY varied from --- to +++ (indicating an increasing representativeness of the focal category, numbered 1 to 6 for purposes of analysis). CE ranged from 1 to 10.

Subjects

Subjects were student volunteers, who received Dfl.15 for participation. A total of 36 subjects, 18 women and 18 men, were randomly assigned to one of the conditions formed by combination of the three between-subjects variables. To each possible combination of three ranges of typicality, two types of information and three problems, two subjects were assigned, one man and one woman.

Results and discussion

Data were collapsed across problems and order of test exemplars. The 0.05 level of statistical significance was employed. Post hoc comparisons on interactions were carried out with Tukey's test, adjusted as per Cicchetti (1972).

Learning

To trace the amount of attention paid to the stimuli in the learning phase, an

analysis of variance (ANOVA) was performed on stimulus inspection times (ST). Table 2 summarizes mean ST's. It shows that amount and kind of experience influenced the time spent on a face.

Main effects of learning phase, TCV and category were significant ($F(4, 120) = 44.48$, $F(2, 60) = 5.66$, and $F(1, 30) = 52.86$, respectively), representing a decreasing ST from beginning to end, and from L to H TCV. Furthermore, subjects studied focal faces longer than those of the contrasting category. This yielded especially in the beginning, as indicated by a significant learning phase $\times$ category interaction ($F(4, 120) = 4.29$). Significant interactions of learning phase with typicality range ($F(4, 120) = 4.11$), type of information ($F(4, 120) = 3.69$), and TCV ($F(8, 240) = 3.04$) indicated that the effects of these variables emerged over time. Post hoc analyses showed significant effects only in the last two learning blocks: faces were viewed quicker in the small- than in the limited- or broad-range condition, longer with specific than with non-specific information, and longer when they were of L rather than H TCV.

Performance on the short classification tests of the learning phase improved during learning. Mean results of the first two (begin) and the last (end) two tests were computed. A MANOVA was performed on CE, RT and TY. Data were collapsed across variant typicalities of the focal exemplars. Typicality range (small vs limited vs broad), type of information (specific vs non-specific), learning phase (begin vs end), TCV (H vs L), and category (+ vs -) were varied. Learning phase was significant ($F(3, 28) = 8.76$); performance improved with learning.

Table 2

Mean stimulus inspection times (ST) in seconds in the different learning phases and learning conditions of experiment 1.

Condition	Learning Block				
	1	2	3	4	5
Typicality range					
Small	19.33	16.98	13.75	11.19	9.48
Limited	19.92	20.04	19.49	16.19	15.55
Broad	19.47	16.92	16.24	15.58	13.96
Information type					
Specific	19.22	18.23	17.42	15.55	14.54
Non-specific	19.92	17.73	15.56	13.08	11.45
Total cue validity					
H	19.18	17.85	16.33	13.42	12.30
M	20.21	17.32	16.33	14.00	12.78
L	19.33	18.77	16.83	15.54	13.91
Category					
Focal	21.49	19.34	18.15	15.54	13.62
Contrasting	17.66	16.62	14.84	13.10	12.37

Frequency

One of the major variables, frequency in the contrasting category, was varied among values having the same frequencies in the focal category. Low contrasting frequency was predicted to facilitate classification and to increase representativeness. Performance on the incomplete test faces directly reflected the influence of contrasting category experience. In the tests following learning, faces lacking one dimension were classified worse the less frequently the missing relevant value occurred in the contrasting category. In a MANOVA on these faces, typicality range, type of information, and absence of dimension were varied, and main effect of absence of dimension was significant ($F(6, 25) = 8.20$). TY and CE increased and RT decreased significantly in the absence of dimension A, B and C, respectively. The A-C contrast was significant. On the B-C contrast, only CE was significantly lower when B rather than C was missing. Performance on faces that lacked two relevant dimensions improved the less frequently the only present relevant value occurred in the contrasting category. In classification of these faces, speed, certainty and judged representativeness were inversely related to contrasting frequency of the value present. The statistical significance of this effect was demonstrated by MANOVA on these faces, performed like the one just mentioned. Main effect of presence of dimension was significant ($F(6, 25) = 11.99$). TY and CE decreased and RT increased significantly when dimensional value A1, B1 or C1 was present, respectively. Both A-C and B-C contrasts were significant.

Pairwise comparison of the same faces showed that A1 was significantly more often chosen as representative of the focal category than was value B1 ($\chi^2 = 9$, $df = 1$). B1 was significantly more often chosen than C1 ($\chi^2 = 25$, $df = 1$). Mentioning the characteristic features and their importance – at the conclusion of the experiment – also revealed the influence of the contrasting category. Frequencies with which the relevant values were mentioned differed significantly (Cochran Q test, $Q = 95.86$, $df = 2$), with decreasing frequency from A1 to B1 to C1. The judgments of importance also differed (Friedman two-way ANOVA, $\chi^2 = 37.04$, $df = 2$). A1 was significantly more frequently judged as more important than B1 ($\chi^2 = 26.47$, $df = 1$). The order of B1 and C1, however, did not differ significantly.

In sum, the results distinctly show how frequency of relevant values in a contrasting category affects category learning. Obviously, the learner keeps track not only of the extent to which a value goes with one category, but also of its occurrence in a contrasting category. Values that provide the sharpest contrast within the domain are considered most characteristic of the category and most important as a basis for classification decisions. The findings of the present experiment amplify the Das-Smaal and De Swart (1984) study. Influence of the contrasting category appeared not to be restricted to whether or not a value occurs in that category. Also frequencies other than zero are of influence.

High total cue validity was expected to facilitate classification performance. This expectation was satisfied in all respects. In the last phase of the learning task, subjects needed less time to study high than low TCV faces. This points to faster learning of high TCV faces. Both in the short classification tests during the learning phase and in the subsequent classification test, certainty and classification speed increased with increasing TCV, despite the shorter ST's on H TCV items during learning. In the MANOVA of the short classification tests, TCV was significant ($F(3, 28) = 16.73$),

Table 3

Mean performance scores on focal and contrasting category faces of varying total cue validity groups in the classification test of experiment 1.

Dependent variable	Total cue validity group					
	Focal category			Contrasting category		
	+++	++	+	-	--	---
CE	7.63	6.31	5.75	6.22	6.53	6.89
RT	5.74	7.65	8.45	7.31	7.13	5.77
TY	5.67	4.65	3.63	2.50	2.42	1.72

reflecting better performance on H than on L exemplars. TCV interacted significantly with category ($F(3, 28) = 59.11$), and this indicated that in the focal category TY increased from L to H, whereas in the contrasting category, the opposite occurred. In a MANOVA on the first 16 faces of the classification test, typicality range (small vs limited vs broad), type of information (specific vs non specific), TCV (H vs M vs L), and category (+ vs -) were varied. TCV was significant ($F(6, 25) = 7.08$). Table 3 shows mean performance scores on faces of H and L TCV.

The TCV effect represented a significant increase in CE and TY and a decrease in RT from L to M to H TCV. Again, TCV interacted significantly with category ($F(6, 25) = 26.59$), due to the divergence in TY between focal and contrasting category exemplars from L to H TCV. Thus, it appeared that representativeness judgments in the classification tasks were positively related to TCV.

From the pairwise comparisons, a ranking of the five focal category faces of different TCV's was established for each subject. Agreement among rankings was significant (Kendall's Coefficient of Concordance, $W = 0.67$, $\chi^2 = 96.95$, $df = 4$). The mean ranking was the same as the ordering according to TCV. All mutual differences among the mean ranks were significant, except for the ranks of the two lower TCV exemplars (χ^2 test, $df = 1$). Because TCV was explicitly learned in the specific information condition, pairwise comparison results were calculated apart for either type of information condition. Mean ranking appeared to be the same as the TCV ranking in both conditions separately. With specific information, the difference between both M TCV exemplars was non-significant. Apart from that, both in the specific and in the non-specific information condition, all mutual differences among the mean ranks were significant, except for the ranking of the two lower TCV exemplars (χ^2 test, $df = 1$). Although the latter non-significance is a weak datum, it is potentially interesting because it replicates a finding of Das-Smaal and De Swart (1984). They also found differential performance on these exemplars in the classification, and not in the comparison task. The disagreement was explained by task difference. One of the two lower TCV exemplars included the distinctive value (A1), whereas the other did not. In line with Tversky and Gati (1978), Das-Smaal and De Swart suggested that a distinctive value is weighted more heavily when differences between categories are relevant, as with classification, than when similarity within a category has to be judged, as with pairwise comparisons. This explains why in the

classification but not in the comparison task the lower TCV face with the distinctive value was judged more representative than the face without this value.

The results on TCV support the idea of Rosch (1973) that categories are structured according to the principle of maximization of cue validity. Exemplars which are categorized best are the ones that have the most in common with exemplars of the same category, and at the same time share the least with items outside the category.

Typicality

ST data showed that at the end of learning the stimuli were viewed for a shorter period of time in the small than in the broader range conditions. This points to greater ease of processing the small range of typical variants than a broad range of both typical and atypical variants.

As predicted, the effect of typicality appeared to be dependent on category and on range of typicality experienced during learning. In the focal category, effect of typicality was present with small- but not with broad-range experience. In the short classification tests, the effects were tested by comparing TY responses on typical (variant 1) with those on medium typical (variant 4) exemplars, for each typicality range condition. Only with small-range experience, TY was significantly higher with variants 1 than with variants 4 ($t = 2.50$, $df = 30$). The effect developed with increasing experience; it showed up only in the last two tests of the learning phase. Mean TY results on variant typicality of the first 16 faces of the classification test are given in table 4 for each typicality range. The following typicality effects held for the focal category. In the small-range condition, TY on variants 1 was significantly higher than on variants 4 ($t = 2.07$, $df = 18$). CE and RT did not differ significantly. Neither in the limited-, nor in the broad-range condition, significant differences were found. Thus the range of value variants constituting the context in which the faces are learned, influences typicality judgments. These results are in line with the suggestion of Das-Smaal and De Swart (1984); broad-range experience compresses the focal category. As a result, typicality differences diminish relative to the small-range condition, and this was actually found. Number of variants experienced during learning did not affect the typicality effect, for no difference between broad and limited experience

Table 4

Mean TY ratings on exemplars of different variant typicalities following small-, limited- or broad-range experience in experiment 1.

		Typicality range experience		
		Small	Limited	Broad
Focal category				
Variants	1	4.96	4.69	4.31
	4	4.65	4.49	4.32
Contrasting category				
Variants	7	1.69	2.81	2.53
	5	1.83	1.75	2.39

turned up. In contrast, category width is the main difference between small and limited experience. The typicality effect was more pronounced with small-range experience, and this can only be ascribed to category width.

Regarding the contrasting category, effects were tested on variants 5 and 7 exemplars of the first 16 faces from the classification test. No typicality effect was found with small-range experience. With broad-range experience only certainty was affected by typicality of variants, with greater certainty on more typical variants ($t = 2.23$, $df = 30$). The items in the limited-experience condition differed significantly on TY, CE and RT ($t = 4.46$, $t = 1.81$ and $t = 1.88$, respectively, $df = 30$). TY and RT were lower, and CE was higher with medium than with atypical items. Das-Smaal and De Swart (1984) also found no typicality effect in the contrasting category with small-range experience. They ascribed this lack of effect to classification by default. Small-range subjects formed a focal category of small extension. Together with the instructions' emphasis on the focal category, this could have led subjects to categorize items of the contrasting category quickly by default, irrespective of their typicality. In the present study indeed a smaller extension of the focal category was formed with small- than with limited- or broad-range experience. This appeared from the 12 test faces that ranged from highly typical of the focal category to highly typical of the contrasting category. In the broad- and in the limited-range experience conditions, atypical focal exemplars (composed of variants 7) were classified significantly more frequently in the focal than in the contrasting category ($\chi^2 = 3.00$ and $\chi^2 = 8.34$, respectively, $df = 1$). Following small-range experience, however, these exemplars were classified equally often in both categories ($\chi^2 = 0$, $df = 1$). In all range conditions, atypical contrasting category items were classified in the contrasting category significantly more frequently than in the focal category ($\chi^2 = 8.34$, $df = 1$ in all cases).

The explanation of classification by default was further supported by the finding that contrasting category items were classified relatively fast in the small-range condition. RT's were significantly lower in the small- than in the broad-range condition ($t = 2.05$, $df = 30$); the other comparisons were non-significant. Furthermore, the distance between categories appeared to be larger in the small- than in the broad-range conditions. This appeared from TY comparisons between the small- and the broad-range conditions for each variant typicality apart on the data of the first 16 test faces (see also table 4). Both with typical (1) and with medium typical (4) focal exemplars, TY was significantly higher in the small- than in the broad-range condition ($t = 4.41$ and $t = 2.26$, respectively, $df = 18$). Both with atypical (7) and medium typical (5) contrasting category items, TY was significantly lower (that is, at a greater distance from the focal category) with small- than with broad-range experience ($t = 3.55$ and $t = 2.45$, respectively, $df = 30$). Thus, typicality judgments of focal and of contrasting category faces were more polarized in the small-range condition. Finally, the finding that subjects took more time to study the focal category than the contrasting category is in line with a classification by default explanation, which presupposes more attention for the focal category.

Overall effect of typicality of variants was tested on the 12 test faces just mentioned, by comparing typical with atypical focal exemplars (variants 1 to 7, respectively). In the broad-range condition, TY and CE were significantly higher with typical than with atypical variants ($t = 12.63$, and $t = 1.71$, respectively, $df = 60$), and RT was lower,

though non-significant ($t = 1.52$, $df = 60$, $p < 0.10$). In the limited-range condition, TY and CE were higher and RT was significantly lower with typical than with atypical variants ($t = 4.42$, $t = 2.11$ and $t = 3.67$, respectively, $df = 60$). The same effect could not be tested properly in the small-range condition, as in this condition variants 1 were experienced before, whereas variants 7 were not. In general, high variant typicality facilitates classification, but the effect depends on category and range of variants forming the learning context. The latter variable also affects the category boundary and intercategory distance as judged by the subjects.

Information on representativeness

The third issue of the present experiment was the effect of the specificity of feedback during learning. Das-Smaal and De Swart (1984) found that specific feedback on representativeness of faces did not facilitate classification. It was suggested that the time to process the information was too short to process the specific information, making it confusing rather than useful. To exclude the possibility of confusion of response and feedback, the present learning task was self-paced, and no classification response was required. At the end of learning, stimulus times appeared to be larger with specific than with non-specific information. This would favor the shortage of processing-time explanation. However, the test results still showed no advantage worth mentioning of presenting additional information on representativeness. In the MANOVA of the first 16 faces of the classification test there was no significant main effect of type of information, but type of information interacted significantly with TVC ($F(6, 25) = 2.61$). On CE and RT, the H-L difference was larger with specific than with non-specific information. However the difference was still significant in the latter condition. Pairwise comparisons showed exactly the same rankings of faces in both conditions. The results rule out the shortage of processing time explanation.

The second explanation proposed by Das-Smaal and De Swart seems most viable in view of the present results. This explanation implies that evaluation of the information on representativeness is a relatively autonomous process. Test results showed that TCV data were gathered and processed to organize the categories in the non-specific information condition as well as in the specific information condition. Thus, in a case where information on representativeness is implicitly given, subjects do not gain from explicit information presentation. This conclusion is in line with Kellogg et al. (1978).

Experiment 2

This experiment was designed to investigate influence of experience with a contrasting category on categorization by showing, or not showing, items of the contrasting category during learning. Furthermore, the effect of conjoint frequency of values was examined. The same type of tasks and apparatus as in experiment 1 were employed.

Method

Stimuli

Stimulus material was the same as in experiment 1, except for the hair section. To study conjoint frequency effects, two hairstyles were employed – fair, straight hair and

dark, curly hair – with four variants each. In the test tasks there were two other hair sections. These were a hair section with almost shaved effect (neutral hair), and a hair section completely covered by a flat cap (covered hair).

Design and procedure

Procedure and trial composition were the same as in experiment 1. Categories were composed as in experiment 1 (see table 1). Hairstyle, however, was varied systematically within subjects to test the conjoint frequency effects. Both types of hairstyle each appeared equally often, in focal as well as contrasting category. Thus, hairstyle by itself was irrelevant to classification. However, dark, curly hair (D1) had a high conjoint frequency with value A1, whereas fair, straight hair (D2) was made more redundant with value B1 in the focal category. Value C1 had about the same conjoint frequency with either hairstyle (see table 5). Variants of both hairstyles were employed randomly. In the test tasks, variants 1 were used on all values.

Category experience was another new variable. Half of the subjects learned from both categories. The other half was shown only the focal category exemplars. Subjects in the two-category condition were instructed as in experiment 1, except that they were not told about the relevancy or irrelevancy of hairstyle. Subjects who were shown only the focal category were instructed in the same way, with omission of remarks about a contrasting category. In this case, subjects were told that they would be presented with faces of men from one family, and that they had to learn to know this family by observing the faces in the learning task. To prevent the subjects from considering the classification tests as mere recognition tasks, they were told that the family members were not shown exhaustively during learning.

Training task. Like in experiment 1, omitting category indication in the one-category condition.

Learning task. The five learning blocks were identical to those from the broad-range, non-specific information condition in experiment 1, except for the change in hairstyle described above (see table A.1). In the one-category condition, only the 10 focal category exemplars from each block were shown, and category information was omitted.

Table 5

Conjoint frequencies of characteristic values A1, B1 and C1, and hairstyles D1 en D2 in the learning task of experiment 2.

	Focal category			Contrasting category		
	D1	D2	Total frequency	D1	D2	Total frequency
A1	25	10	35	0	0	0
B1	10	25	35	10	0	10
C1	17	18	35	10	15	25

Tests during learning. In the first two tests, influence of contrasting category experience was tested. The test contained faces with two relevant values (A1B1, B1C1 and A1C1), and faces with one relevant value (B1 and C1). Each face occurred twice, with either value 2 or 3 on the other dimensions. All faces had neutral hair. The last two tests were a repetition of the first tests.

To test the influence of conjoint frequency, hairstyle was varied in the third test. Two sets of three faces were presented. The three faces had either value A1, B1, or C1. Values on the other dimensions were not characteristic of the focal category (values 2 or 3). One of the sets had hairstyle D1, the other set had hairstyle D2. Order of presentation was randomized.

Classification task. The task consisted of 21 faces, preceded by one habituation trial. TCV as well as hairstyle was varied in 14 faces, presented in random order. Eight faces of different TCV (and neutral hair) were employed. These were one without and one with all relevant values, three with one of the three relevant values each, and three with the combinations possible with two relevant values on each face. The remaining dimensions had value 2 or 3, chosen randomly. Hairstyle was varied on another six faces. These were two sets of three faces. One set had hairstyle D1, the other had hairstyle D2. Each set consisted of one face with characteristic value A1, one with B1, and one with C1. Values on the other dimensions were non-characteristic values 2 or 3. Each set contained identical faces except for hairstyle.

The last seven faces were the same incomplete faces as employed in the classification task of experiment 1. Hair, however, was covered by a cap.

Pairwise comparisons. The same comparisons as in experiment 1 were given, in the same order. However, the neutral hairstyle was employed on the faces. Five new comparisons were added. These were presented in between the pairs of faces with different TCV and the incomplete faces. The first new comparison was intended to habituate to value omission. Next, three comparisons were to be made between incomplete faces, showing just two values. A1D1 was compared with A1D2, B1D1 with B1D2, and C1D1 with C1D2, in random order. Finally, two A1B1C1 faces were compared, one with hairstyle D1, the other with D2.

Subjects

Subjects were 18 student volunteers, nine women and nine men, who had not participated in experiment 1. They were paid Df1.15 each for their services. Three subjects were assigned randomly to each combination of two types of category experience and three problems. Men and women were divided equally over the levels of the between-subjects variables.

Results and discussion

Contrasting category

Category learning occurred either with focal exemplars only, or with both focal and contrasting category instances. The three characteristic values of the focal category had

the same frequency in the focal category. However, their frequencies in the contrasting category differed. Experience on the contrasting category appeared to reflect these differences. In the two-category condition, exemplars with values of equal focal frequency were classified better and judged more representative the higher their TCV. In the one-category condition, performance on these exemplars did not differ. In the short classification tests, influence of experience on the contrasting category was tested on mean results except for the third test, which measured conjoint frequency effects. CE, RT and TY data were analyzed with planned comparisons within either category experience condition. Comparisons were made among the three focal category exemplars with two characteristic values (A1B1, A1C1, and B1C1), and between the two contrasting category items with one characteristic value (B1 and C1). Within the two-category condition, the mutual differences among the three focal category exemplars were significant each time on at least two of the three dependent variables ($t > 1.70$, $df = 32$). In this condition, both contrasting category items differed also significantly ($t = 2.15$, $t = 3.16$, and $t = 2.73$ with CE, RT and TY, respectively, $df = 16$). The results showed better performance and increased typicality with higher TCV. As predicted, in the one-category condition none of the differences reached significance. In the subsequent classification task, the interaction of TCV and category experience was examined in a MANOVA on CE, RT and TY data of the eight faces of different TCV. Data of the two focal faces of H and those of M TCV were averaged. Category experience (two vs one), category (+ vs -), and TCV (H vs M vs L) were varied. TCV and category experience interacted significantly ($F(6, 11) = 5.90$), reflecting improved performance with increasing TCV following two-, but not with one-category experience. Representativeness rankings in the comparisons task followed the TCV ordering in the two-category condition. With experience on one category, faces were ranked according to frequency of values in the focal category. Binomial tests showed that in both experience conditions, the highest TCV exemplar was ranked significantly higher than the other ones, as predicted. In the two-category condition, the ordering of the other exemplars was the same as the ranking according to TCV. All mutual differences among the mean ranks were significant, except for the difference between the exemplars of next highest and between the exemplars of lowest TCV. In the one-category condition, the ordering was the same as the ranking according to frequency in the focal category, implying equal rankings of the three exemplars with two characteristic values. The exemplar with one characteristic value was not ranked significantly lower than these exemplars. Subjects with experience on two categories showed more agreement on ranking than subjects in the one-category condition. Ranking agreement among subjects with two-category experience was significant (Kendall's Coefficient of Concordance, $W = 0.85$, $\chi^2 = 30.49$, $df = 4$). In the one-category condition, the agreement did not reach significance ($W = 0.23$, $\chi^2 = 8.27$, $df = 4$, $p < 0.10$). This difference can be explained. More equal rankings of exemplars were expected in the one-category condition, but subjects always had to make some choice in a comparison. Hence, lower agreement automatically follows.

Category experience effects were also apparent from performance on incomplete faces, both in the classification and in the comparisons task. The faces showed the expected cue validity effects when either one or two dimensions were missing following two, but not one category, experience. In the classification task, CE, RT and TY

performance on the three faces that lacked one dimension was analyzed employing a MANOVA. Category experience (two vs one) and absence of dimension (A vs B vs C) varied. The only significant effect was the category experience $\times$ absence of dimension interaction ($F(6, 11) = 5.80$), which reflected an effect of frequency in the contrasting category following two-, but not following one-category experience. CE increased and RT decreased with lack of dimension A, B and C, respectively, in the two-category condition.

A MANOVA was also computed for the faces in which only one relevant value was present. Category experience (two vs one) and presence of dimension (A vs B vs C) varied. Presence of dimension was significant ($F(6, 11) = 3.39$), and interacted significantly with category experience ($F(6, 11) = 4.09$). Again, this indicated an effect of frequency in the contrasting category following two-, but not following one-category experience. CE and TY decreased and RT increased when A1, B1 or C1 was the only value present, respectively.

The same faces that lacked two relevant dimensions were also compared pairwise. With experience on two categories, eight of nine subjects chose A1 as more representative than B1 (binomial test, $p < 0.02$). Seven out of nine chose A1 above C1 ($p < 0.09$), and six out of nine chose B1 above C1 ($p > 0.10$). Following one-category experience all differences were non-significant.

With two-category experience, frequency of mentioning the characteristic values was expected to be positively related to cue validity. A1, B1 and C1 were mentioned 8, 8 and 6 out of nine times, respectively, in the two-category condition, and 7, 7 and 6 times in the one-category condition. In both conditions the differences were non-significant (Cochran's Q test). A ceiling effect can explain the lack of difference, because all values were mentioned relatively often. Judgments of importance of these values did, however, differ significantly in the two- but not in the one-category experience condition (Friedman two-way ANOVA, $\chi^2 = 7.17$ and $\chi^2 = 1.56$, respectively, $df = 2$). With two-category experience, A1 was significantly more frequently judged as more important than B1 (binomial test). Judgments of B1 and C1 did not differ significantly. Thus, in the two-category condition, the value of the highest cue validity was judged the more important one, whereas experience with one category resulted in equally important characteristic values.

Lack of experience with the contrasting category had another effect. It diminished difference between categories as measured by representativeness of exemplars. Although overall classification test performance was the same in both experience conditions, contrasting category items were judged more representative of the focal category following one-, than following two-category experience. This appeared from the classification test MANOVA on the eight different TCV faces. It showed a significant interaction category experience $\times$ category ($F(3, 14) = 9.78$), reflecting a higher TY on contrasting category items with one- than with two-category experience, whereas TY on focal exemplars did not differ.

In sum, the results reported here are clearly supportive of models that take into account frequency of occurrence of values in a contrasting category. The various test tasks demanded different utilization of the acquired information, but performance on all tasks was influenced by the contrasting category composition when subjects had learning experience on that category. The results cannot be ascribed to differences in

focal face exposure during learning. An ANOVA on ST's of the focal exemplars showed no significant differences between both category experience conditions. Main factors corresponded to category experience (two vs one), learning phase (block 1 to 5), and TCV (H vs M vs L). Of all main and interaction effects only learning phase was significant ($F(4, 64) = 12.84$), showing that with continued learning, faces are studied gradually shorter.

Conjoint frequency

The second issue of the present experiment was the controversy on conjoint frequency effects. One point of view is that stimulus dimensions are independent and that only simple frequencies are represented (Kellogg 1981). Others suggest that not only simple frequencies but also conjoint frequencies affect categorization (Rosch 1975; Hayes-Roth and Hayes-Roth 1977; Medin and Schaffer 1978). Medin et al. (1982) investigated the effects of conjoint frequency in a simulated medical diagnosis task. They concluded that correlation of symptoms influenced category judgments. Unfortunately, however, in most of the tests correlatedness was confounded with experience. The test cases with correlated symptoms were cases that were presented in the learning task, whereas the test cases with uncorrelated symptoms were new. As only a small number of learning cases was employed, the confounding is detrimental to the validity of their conclusion.

The present study varied the co-occurrence of relevant and irrelevant values, keeping the simple frequencies constant. The data argue against a simple frequency theory. Although reaction times were not affected, conjoint frequency of values increased classification certainty and representativeness judgments relative to non-redundant occurrence of values. Hairstyle by itself was irrelevant to classification. However, D1 occurred often with A1, and D2 often with B1 in the focal category.

In the third short classification test, performance on each of the D1 faces was compared with performance on that same face with hairstyle D2. The Wilcoxon matched-pairs signed ranks test was employed. None of the RT differences were significant. CE and TY were significantly higher on face A1D1 than on A1D2 ($T = 20$, $N = 15$ and $T = 13$, $N = 13$, respectively), whereas CE was significantly lower on face B1D1 than on B1D2 ($T = 23$, $N = 15$). TY did not differ significantly in the latter case. As expected, performances on face C1D1 and on C1D2 did not differ significantly. In the classification test following learning, effect of conjoint frequency was tested in the same way. Again, none of the RT differences were significant. CE and TY were significantly higher on A1D1 than on A1D2 ($T = 6$, $N = 10$, and $T = 0$, $N = 8$, respectively), whereas CE was significantly lower on B1D1 than on B1D2 ($T = 15.5$, $N = 13$), the TY difference being non-significant. C1D1 and C1D2 did not differ significantly, as predicted.

Pairwise comparisons also showed conjoint frequency effects. Again, effects were tested on faces with different hairstyles. In this test, comparisons were made among faces lacking two dimensions and showing just one characteristic value, either with hairstyle D1 or with D2. A1D1 was judged significantly more representative than A1D2 ($\chi^2 = 5.56$, $df = 1$). B1D1 and B1D2 did not differ significantly, neither did C1D1 and C1D2. D1 and D2 were also compared on the A1B1C1 face. Overall, the D1 hairstyle was judged significantly more representative than D2 ($\chi^2 = 3.56$, $df = 1$).

When tested apart for both experience conditions, this result appeared to yield in the two-category condition only (binomial test). This is to be expected, because in the one-category condition A1 has no special status compared to B1 (or C1), so in this condition there is no reason why D1 should be judged more representative than D2.

At the conclusion of the experiment, hairstyle was mentioned as a characteristic feature in some cases. D1 was more often mentioned than D2 in the two-category condition, whereas in the one-category condition there was no significant difference (binomial test).

Thus, correlation with a value of high cue validity increased the representativeness of an irrelevant value. Conjoint frequency had the highest effect with the characteristic value that was most important to classification, value A1. This finding offers an explanation as to why the experiment of Kellogg failed to produce a conjoint frequency effect. In the Kellogg experiment, the characteristic values with which conjoint frequency was varied were all irrelevant to classification. A simple affirmative rule applied, with one separate defining value, and this made the other values relatively unimportant to classification. Dimensional dependence may therefore only occur when subjects pay attention to at least one of the dimensions, as in the present experiment, where the characteristic values were relevant to classification. The present results argue that theories on category learning should not, when categories become organized, assume independence of all dimensions. At least the values that are relevant to classification add to the weight of values with which they correlate.

General discussion

The present study addressed several issues relating to the topic of variation among categorical exemplars. It was shown that frequency of values and typicality of value variants both contribute to within-category variation.

Frequency of occurrence in the focal category has been found before to be a major factor in category formation (Goldman and Homa 1977; Hayes-Roth and Hayes-Roth 1977; Kellogg et al. 1978; Neumann 1974). However, another factor that a theory of categorization will have to encompass is the influence of occurrence of values in a contrasting category. Influence of a contrasting category is clearly revealed in various kinds of test performances in the present experiments. Characteristic values with equal frequencies in the focal category, improved classification performance and were judged more representative and important to classification the lower their frequency in the contrasting category. Furthermore, experience on both the focal and the contrasting category resulted in contrasting category effects, whereas experience only on focal exemplars did not. Performance in the latter case

was guided by focal frequency. Influence of the contrasting category was not limited to whether or not a value occurred in that category. In extension to the Das-Smaal and De Swart (1984) results the present study showed that frequency variation beyond all-or-none affected categorization. It was shown that the expression of frequency in terms of cue validity accounts for these effects. The specific information manipulation in experiment 1 showed that cue validity information was gathered independently of whether or not the information was explicitly given.

The present study also showed that stimulus dimensions interact in category learning. Correlation of values altered the representativeness. High conjoint frequency of a non-characteristic irrelevant value and a characteristic relevant one, increased the importance of the non-characteristic value.

Thus, the results are supportive of a model of categorization that takes into account frequency in focal and contrasting category as well as conjoint frequency of values. The property-set model proposed by Hayes-Roth and Hayes-Roth (1977) is such a model. The model assumes that both simple and conjoint frequencies are counted, and that the single value or conjunction of values with the highest cue validity determines how an exemplar is classified. The latter assumption seems too simple in the light of the present results. The model does not account for our clearly established effects of total cue validity, but the model can be adjusted in light of our results. In an adjusted model, a cue, like a property-set, again would be taken as a value or a combination of values. However, the sum of cue validities rather than the highest cue validity would be assumed to determine classification. The conception of cue as a combination of values does not change our order of exemplars according to TCV and is therefore in agreement with the results. This conception does, however, account for conjoint frequency effects, and therefore seems to be justified.

However, rather than proposing one particular model, the present approach was meant to constrain possible models on some issues. Frequency was one of the issues studied. Typicality of value variants was another. Representativeness of instances appeared to be determined also by variant typicality. Classification was less difficult the more typical the value variants were to their prototypical value. The effect of typicality showed the interaction of category and range of typicality experienced during learning, which was found before by

Das-Smaal and De Swart (1984). The explanations they suggested were supported by the present results. Categorization by default explains why the typicality effect was absent in the contrasting category following small-range experience. Category compression of a broad category explains why in the focal category typicality differences did show up with small- but not with broad-range experience. Small- as compared with broad-range experience had the effect of increasing the distance between categories. Representativeness judgments in the classification task showed that the inter-categorical distance was larger with small- than with broader-range experience. Thus, the same physical distances between category exemplars were judged differently, dependent on range of experience. This indicates a difference between psychological and physical space.

The range effects found in the present study and by Das-Smaal and De Swart (1984) show how category experience during learning affects subsequent classification. Category experience influences boundary and distance between categories, as well as typicality differences within categories. Categorization models should be able to account for these effects.

Goodness of example of instances was manipulated in the present experiments by variation of frequency and typicality of value variants. Das-Smaal and De Swart (1984) showed that these two variables acted independently of each other. The question of how the two aspects can be accounted for in one model has to do with the problem of how values are represented. Assuming a multi-dimensional space, representations may be modeled in terms of either points or regions in the space. The assumption of points, however, amounts to the assumption of a region. When points are assumed, and a newly experienced value variant is identified as the value to which it is closest, it is necessary to assume also boundaries that determine to which value a particular variant is assigned. Boundaries enclose a region. As Neumann (1977) pointed out, representing the frequency of an interval presents no particular problem. Thus, a frequency model can be used to explain not only the frequency effects mentioned above, but it can also be elaborated to deal with the variant typicality effects by assuming interval representation.

When intervals on a continuous dimension are assumed, the following can be stated. The number of intervals on a dimension would depend on the number of values a subject distinguishes. A dimension

with high resolution (Palmer 1978) has many values, whereas a less fine-grained dimension may contain just a few. The same dimension may be represented with different resolutions, for instance by experts and by laymen, due to experience. The present study demonstrated that kind of experience influences the intervals. A focal category of relatively small extension was formed following small-range experience. That is, the intervals of the focal values allowed less atypical variants when they were established with small- than with broad-range experience.

References

- Cicchetti, D.V., 1972. Extension of multiple-range tests to interaction tables in the analysis of variance: a rapid approximate solution. *Psychological Bulletin* 77, 405–408.
- Das-Smaal, E.A. and J.H. De Swart, 1981. Typicality, physiological activity and concept identification. *Acta Psychologica* 47, 1–24.
- Das-Smaal, E.A. and J.H. De Swart, 1984. Variation within categories. *Acta Psychologica* 57, 165–192.
- Goldman, D. and D. Homa, 1977. Integrative and metric properties of abstracted information as a function of category discriminability, instance variability, and experience. *Journal of Experimental Psychology: Human Learning and Memory* 3, 375–385.
- Hayes-Roth, B. and F. Hayes-Roth, 1977. Concept learning and the recognition and classification of exemplars. *Journal of Verbal Learning and Verbal Behavior* 16, 321–338.
- Kellogg, R.T., 1981. Feature frequency in concept learning: what is counted? *Memory and Cognition* 9, 157–163.
- Kellogg, R.T., L.E. Bourne and B.R. Ekstrand, 1978. Feature frequency and the acquisition of natural concepts. *American Journal of Psychology* 91, 212–222.
- Medin, D.L. and M.M. Schaffer, 1978. A context theory of classification learning. *Psychological Review* 85, 207–238.
- Medin, D.L., M.W. Altom, S.M. Edelson and D. Freko, 1982. Correlated symptoms and simulated medical classification. *Journal of Experimental Psychology: Learning, Memory and Cognition* 8, 37–50.
- Neumann, P.G., 1974. An attribute frequency model for the abstraction of prototypes. *Memory and Cognition* 2, 241–248.
- Neumann, P.G., 1977. Visual prototype information with discontinuous representation of dimensions of variability. *Memory and Cognition* 5, 187–197.
- Palmer, S.E., 1978. 'Fundamental aspects of cognitive representation'. In: E. Rosch and B.B. Lloyd (eds.), *Cognition and categorization*. Hillsdale, NJ: Erlbaum.
- Reed, S.K., 1972. Pattern recognition and categorization. *Cognitive Psychology* 3, 382–407.
- Rosch, E., 1973. 'On the internal structure of perceptual and semantic categories'. In: T.E. Moore (ed.), *Cognitive development and the acquisition of language*. New York: Academic Press.
- Rosch, E., 1975. Cognitive representation of semantic categories. *Journal of Experimental Psychology: General* 3, 192–233.
- Tversky, A. and J. Gati, 1978. 'Studies of similarity'. In E. Rosch and B.B. Lloyd (eds.), *Cognition and categorization*. Hillsdale, NJ: Erlbaum.

Appendix

Table A.1

Values and variants of faces from the first three blocks of the learning task. Values (numbered 1 to 3) are given in the column on the left for dimension A, B and C, respectively. Value variants (numbered 1 to 7) are given in the next columns, also for values on dimension A, B and C, respectively. Variants are given for small, limited and broad typicality range condition apart. Total cue validity and category are next indicated for each face. Finally, values and variants on dimension D from experiment 2 are indicated. Values (numbered 1 or 2) are indicated first and variants (numbered 1 to 4) are given next.

Stimulus number	Values on dimensions			Value variants												Total cue validity ^a	Category label	Values + variants on dimension D			
				Typicality range																	
				Small						Limited									Broad		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C						
Block 1																					
1	1	1	1	1	3	4	1	4	7	1	6	7	2.36 (H)	+	1-1						
2	3	3	3	1	1	1	1	1	1	2	1	2	0.85 (H)	-	2-4						
3	3	3	1	2	1	1	4	1	1	4	1	3	1.06 (M)	-	2-2						
4	1	3	1	2	1	3	1	1	7	2	1	7	1.84 (M)	+	1-2						
5	1	2	1	4	2	3	7	1	4	5	3	7	1.87 (M)	+	1-3						
6	1	1	3	2	4	2	1	4	1	1	6	6	2.15 (H)	+	2-4						
7	2	3	2	2	2	1	4	4	1	3	4	2	0.88 (H)	-	2-2						
8	2	1	1	2	4	2	7	7	7	5	6	3	1.60 (L)	+	2-3						
9	3	2	1	2	2	1	4	4	1	2	4	2	1.09 (M)	-	1-1						
10	1	1	1	4	3	1	7	4	1	5	4	1	2.36 (H)	+	1-4						
11	3	1	1	2	3	1	4	7	1	3	7	1	1.58 (L)	+	2-4						
12	2	1	2	1	2	2	1	4	4	1	3	2	1.40 (L)	-	1-3						
13	2	2	3	2	2	1	4	4	1	4	3	1	0.88 (H)	-	1-2						
14	2	1	3	1	2	2	1	4	4	2	3	4	1.39 (L)	-	1-4						
15	1	1	2	1	4	3	4	4	4	2	6	4	2.16 (H)	+	2-1						
16	3	2	1	2	1	1	4	1	1	4	1	1	1.09 (M)	-	2-3						
17	2	1	1	3	2	1	4	1	7	5	2	4	1.60 (L)	+	2-2						
18	1	2	2	4	1	1	7	1	1	4	3	2	1.67 (M)	+	1-2						
19	2	2	1	1	1	1	1	1	1	3	2	1	1.11 (M)	-	1-4						
20	2	3	1	2	1	1	4	1	1	4	3	1	1.08 (M)	-	2-1						

Block 2

1	3	3	1	1	1	1	2	1	1	4	1	4	2	1	3	1.06 (M)	-	2-3
2	2	2	3	1	1	2	1	1	1	4	1	4	3	4	1	0.90 (H)	-	2-3
3	1	3	1	1	4	1	1	1	7	1	1	7	1	1	2	1.84 (M)	+	1-3
4	1	1	1	2	2	1	3	4	4	1	7	3	3	2	5	2.36 (H)	+	2-1
5	1	1	2	3	4	4	4	4	4	4	4	6	5	5	6	2.16 (H)	+	1-3
6	3	1	2	1	2	2	2	1	1	4	4	2	4	4	4	1.38 (L)	-	1-1
7	3	2	1	1	2	2	2	1	1	4	4	1	4	4	3	1.09 (M)	-	2-3
8	3	1	1	1	1	3	1	4	1	4	7	4	4	7	4	1.58 (L)	+	2-2
9	1	1	3	1	1	2	3	1	1	4	7	1	1	3	5	2.15 (H)	+	2-4
10	2	2	1	1	1	1	2	1	2	1	4	2	2	1	4	1.11 (M)	-	2-2
11	3	2	2	1	2	2	2	1	1	4	4	4	2	3	3	0.89 (H)	-	1-3
12	2	1	1	2	2	3	4	7	7	7	7	6	7	5	5	1.60 (L)	+	2-1
13	3	1	1	2	4	2	2	1	1	4	1	1	1	4	3	1.58 (L)	+	2-1
14	1	2	1	4	2	2	3	7	1	1	4	6	1	2	3	1.87 (M)	+	1-2
15	1	1	1	1	1	2	3	1	1	1	7	1	2	2	7	2.36 (H)	+	1-4
16	2	3	1	1	2	2	1	1	1	4	1	2	4	2	2	1.08 (M)	-	1-2
17	3	3	2	2	2	2	1	4	4	4	1	2	3	1	1	0.88 (H)	-	2-4
18	3	1	3	1	1	1	2	1	1	1	4	1	1	1	4	1.37 (L)	-	1-1
19	1	3	3	1	4	2	2	1	1	7	4	2	6	4	4	1.63 (M)	+	1-1
20	2	3	1	2	1	2	2	4	4	1	4	2	2	1	3	1.08 (M)	-	1-4

(continued)

Table A.1 (continued)

Stimulus number	Values on dimensions			Value variants									Total cue validity ^a	Category label	Values + variants on dimension D
				Typicality range											
	Small			Limited						Broad					
A	B	C	A	B	C	A	B	C	A	B	C				
Block 3															
1	3	1	1	1	3	2	1	7	4	1	7	5	1.58 (L)	+	2-1
2	2	2	1	2	1	1	4	1	1	3	2	1	1.11 (M)	-	1-4
3	3	2	1	1	1	1	1	1	1	2	1	2	1.09 (M)	-	2-2
4	3	3	2	2	1	1	4	1	1	3	1	1	0.86 (H)	-	2-3
5	2	1	3	1	2	2	1	4	4	2	4	3	1.39 (L)	-	1-4
6	2	2	2	2	2	1	4	4	1	3	4	2	0.91 (H)	-	2-2
7	1	3	1	1	2	3	1	1	7	3	1	6	1.84 (M)	+	1-1
8	2	1	1	4	1	4	7	1	4	7	2	4	1.60 (L)	+	2-4
9	1	1	1	1	4	1	1	4	1	1	3	2	2.36 (H)	+	1-1
10	3	1	3	1	2	2	1	4	4	1	4	2	1.37 (L)	-	1-2
11	1	2	1	2	4	4	7	7	7	5	6	7	1.87 (M)	+	1-2
12	1	1	3	2	3	3	1	4	7	1	4	6	2.15 (H)	+	2-2
13	2	2	1	2	2	1	4	4	1	3	4	1	1.11 (M)	-	2-1
14	1	1	1	2	4	2	4	7	4	3	7	4	2.36 (H)	+	2-3
15	1	1	2	3	3	1	4	4	4	5	4	4	2.16 (H)	+	1-3
16	2	1	1	2	1	4	4	1	7	3	2	5	1.60 (L)	+	2-1
17	2	3	1	2	2	1	4	4	1	4	4	2	1.08 (M)	-	2-4
18	3	3	1	2	1	1	4	1	1	4	1	3	1.06 (M)	-	1-3
19	3	3	2	1	1	1	1	1	1	2	1	3	0.86 (H)	-	1-3
20	1	2	2	3	1	2	7	1	1	6	1	2	1.67 (M)	+	1-1

^a High, medium and low TCV are indicated in parentheses by H, M and L, respectively.