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Conceptualization of the Reasoning-Test "Culture-referenced Pictographic Analogies"

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Abstract: In this paper a test is proposed which, following the well-known tests asking for lexical analogies, uses a non-verbal analogon with pictures of everyday objects. By this means one out of the six categories of reasoning tests as suggested by Kubinger (2023a) can be realized: the *crystallized* facet with *figural* contents. In two studies a first draft of such a test with 27 items has been psychometrically analyzed according to the Rasch model. Five items resulted as definitely not fitting the model. It is shown, retrospectively, that this is most likely caused by the items' topics and contents: either they refer to highly specialized knowledge, measuring rather the level of general education than deductive thinking (i.e. reasoning) by using objects that are commonly present nowadays; or/and the items' task does not focus on everyday objects' common functions but is rather reduced to associating one object to another. As a consequence an operational definition is given of that ability which the items of a future test *Culture-referenced Pictographic Analogies* should measure.

Keywords:
Reasoning, everyday knowledge, pictograph, multiple-choice response format, Rasch model

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Introduction

Kubinger (2023a) classified reasoning tests into six categories: *fluid* vs. *crystallized* facets which are crossed with *lexical* vs. *numerical* vs. *figural* contents. And he refers to reasoning as the "ability to realize regularities and logically compelling connections in order to put them to appropriate use" (Kubinger, 2019, p. 244; translation by the authors). In this paper a test is proposed which, following the well-known tests asking for lexical analogies, uses a non-verbal analogon with pictures of everyday objects – this idea certainly is trivial. Nevertheless, a test explicitly measuring reasoning with *figural* contents, the looked-for relation of imaged objects based on *crystallized* power, is, to our knowledge, not at the practitioners' disposal for psychological consulting.

Method

Such a test, *Culture-referenced Pictographic Analogies* is fundamentally easy to design. Obviously, for this a multiple-choice response format is best, because drawing a pictograph in a free response format is not reasonable for testees – although a multiple-choice response format always risks a non-zero probability for lucky guessing. As a matter of fact, in this case even some effective psycho-technological response options developed to reduce that probability (e.g. using more than a single response option as a solution; see for details of several approaches to minimize that risk Kubinger, 2014) were not implemented. Instead the simple multiple-choice format "1 out of 5" has been applied – "1 out of 5" meaning that a single answer option out of five is correct. Pictures for the items, distractors included, were either created with http://www.pixlr.com/editor or, most of them, taken from public domains; a few pictures fall under the Creative Commons license. In Figure 1 the instruction item is given. The task is to apply the principle of a mathematical proportionality task, that is to deduce the essential relation (":") of a first and a second everyday object on the left side and to transfer this relation to the right side ("="), where only another first everyday object is presented but the fitting second one is asked – the object in question ("?") being one out of five given options. In this instruction item the essential relation to transfer from the left to the right side is "male *vs.* female"; as the first object on the right side is (a) male (chicken), i.e. a rooster, the solution must be (a) female (chicken), i.e. a hen, option D.

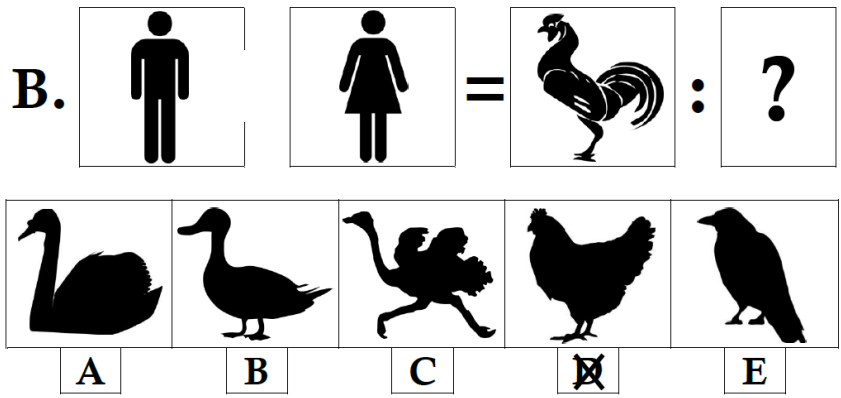

Figure 1
The introduction item of the first draft of the test Culture-referenced Pictographic Analogies. The solution is D. [Public domain:
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The problem rather is, which topics and contents are to be used in such a test – a common problem for education-based knowledge tests. Therefore the constructed items of the first draft for the test *Culture-referenced Pictographic Analogies* might not be representative, furthermore the current item pool is far too small. Nevertheless, there are 27 items which are presented in the following. For reasons of simplicity and copyright, respectively, not all of them are shown visually (see Fig. 2 to 6, as well further down Fig. 8). All items not visually depicted are outlined in Table 1: Each item is described with respect to its used everyday objects and their "proportionality" task (distractors included).

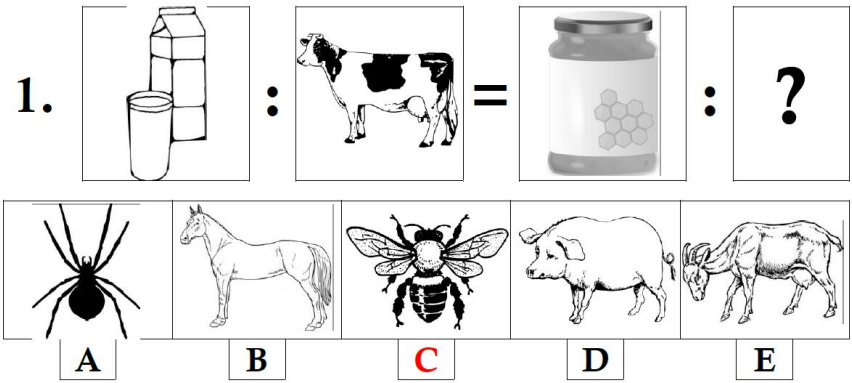

Figure 2

Item 1 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is C. [Public domain:
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http://openclipart.org/image/800px/svg_to_png/162139/Honey_Jar_1.png,
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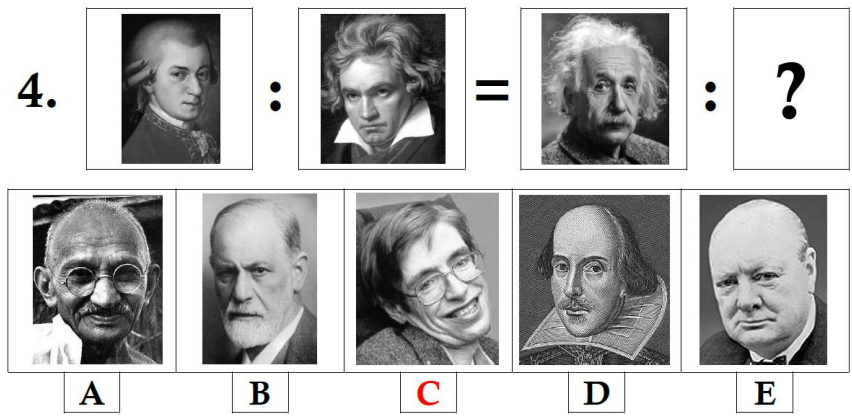

Figure 3

Item 4 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is C. [Public domain:
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http://upload.wikimedia.org/wikipedia/commons/1/14/Albert_Einstein_1947.jpg,
http://upload.wikimedia.org/wikipedia/commons/thumb/0/03/MKGandhi.jpg/396px-MKGandhi.jpg,
http://upload.wikimedia.org/wikipedia/commons/1/12/Sigmund_Freud_LIFE.jpg,
http://upload.wikimedia.org/wikipedia/commons/e/eb/Stephen_Hawking.StarChild.jpg,
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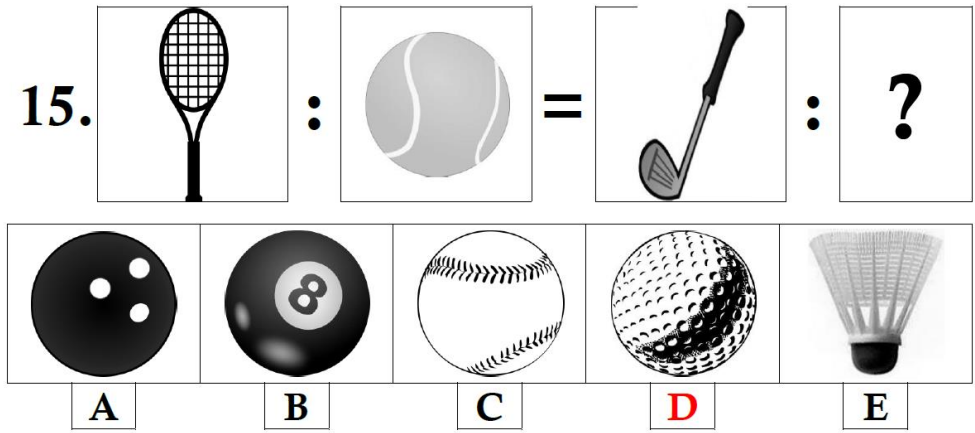

Figure 4

Item 15 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is D. [Public domain:
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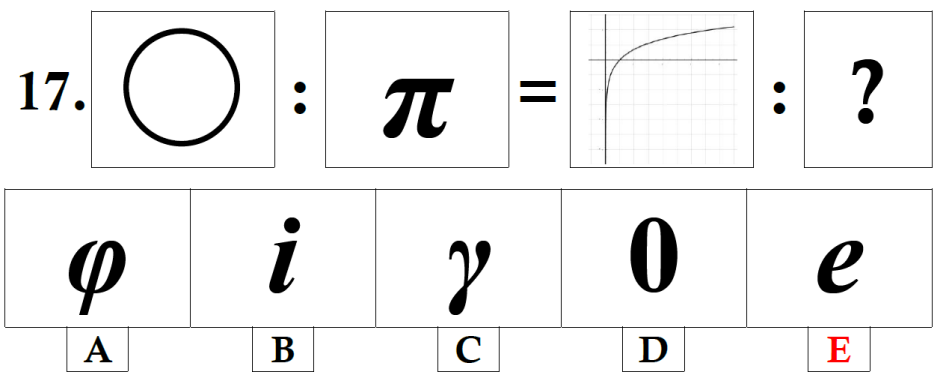

Figure 5

Item 17 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is E. [Sources: Microsoft Word – Shape, Microsoft Word - Times New Roman font, public domain:

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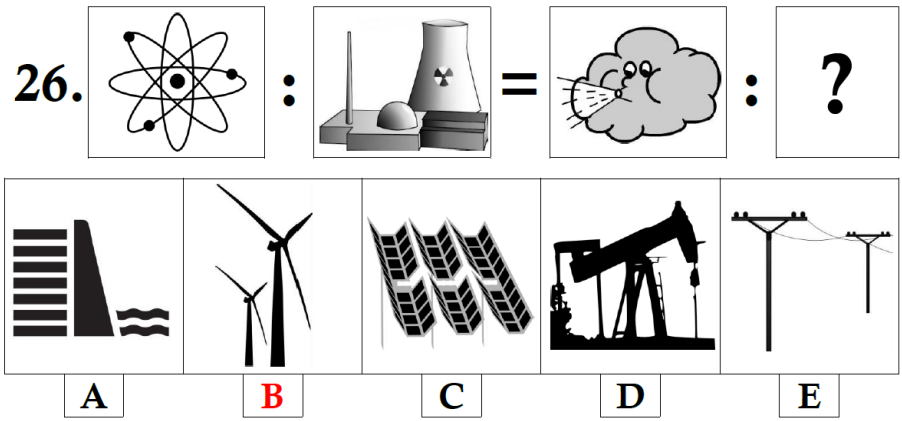

Figure 6

Item 26 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is B. [Public domain: http://www.clker.com/cliparts/y/d/6/h/D/S/black-atom-hi.png, http://www.clker.com/cliparts/5/2/8/2/1206556450916835897qubodup_Reactor.svg.hi.png , *Sources: self-created with* http://www.pixlr.com/editor , *public domain:* http://www.clker.com/cliparts/7/d/0/e/1207431666677656750dam%20white.svg.hi.png, http://www.clker.com/cliparts/x/X/a/I/b/Z/black-wind-turbine-2-hi.png, http://www.clipartmojo.com/clip-art/Solar-Panels-1-2041/ , http://www.clker.com/cliparts/a/1/d/7/1220226400918821922oil%20drill.svg.hi.png , http://openclipart.org/image/800px/svg_to_png/68221/1277193098.png]

Table 1
The items of the first draft of the test Culture-referenced Pictographic Analogies which are not shown visually in their original representation in this paper; here they are just outlined with respect to the used everyday objects and their "proportionality" task (distractors included); the solutions are printed in bold.

item no.	first object left side		second object left side		first object right side			answer option 1	2	3	4	5
3	baseball player	:	baseball field	=	handball player	:	?	track field	basketball court	volleyball court	tennis court	**handball court**
5	typewriter	:	laptop	=	cassette tape	:	?	record player	**CD**	phone	ghetto blaster	computer mouse
6	Taj Mahal	:	India on world map	=	Christ the Redeemer	:	?	China on world map	Russia on world map	Canada on world map	**Brazil on world map**	Algeria on world map
8	caterpillar	:	butterfly	=	tadpole	:	?	**frog**	fly	bird	snake	dragon fly
9	Greek temple	:	Hades	=	pyramid	:	?	Ganesha	**Anubis**	Hera	Vishnu	Neptune
10	warning sign: slippery road	:	warning sign: railway crossing	=	regulation sign: no entry	:	?	… cross-wind	… priority road	**…no U-turns**	…pre-scribed di-rection	… dangerous bend
11	flag of Austria	:	coat of arms of Austria	=	flag of Germany	:	?	coat of arms of Poland	coat of arms of Greek	coat of arms of Albanian	coat of arms of Romania	**coat of arms of Germany**
12	Che Guevara	:	pentagonal red star	=	Vladimir Lenin	:	?	pentacle	**hammer & sickle**	Red Cross flag	peace sym-bol	stylized cir-cle-A
13	mathematical sign: +	:	Greek symbol: capital sigma	=	mathematical sign: · [×]	:	?	mathemati-cal sign:	**Greek: capital pi**	Greek: capital theta	mathemati-cal sign: / [:]	Greek: capital xi
14	fetus	:	woman	=	egg	:	?	**turtle**	bat	dolphin	elephant	camel
16	castle	:	knight	=	Colosseum	:	?	**legionary**	viking	samurai	redcoat	cossack
18	flute	:	trumpet	=	harp	:	?	xylophone	accordion	drum	maracas	**guitar**
19	flag of the USA	:	Dollar sign	=	Flag of the EU	:	?	Baht sign	Yen sign	Franc sign	**Euro sign**	Lira sign
20	building on fire	:	fire extinguisher	=	bleeding finger wound	:	?	**First Aid sign**	radioactive sign	emergency sign	biohazard sign	corrosive sign
21	Greek letters: zrl (ζρλ)	:	flag of Greece	=	Chinese character: China (的中国)	:	?	flag of Russia flag	flag of Egypt	flag of argentinia	flag of Portugal	**flag of China**
22	GMT zone on EU map	:	analog clock: 12:00	=	GMT+1 zone on EU map	:	?	analog clock: 10:00	analog clock: 11:00	**analog clock: 1:00**	analog clock: 2:00	analog clock: 3:00
23	Church	:	Christian cross	=	Pagoda	:	?	**Dharma wheel**	star & crescent	Khanda (Sikhism)	star of David	Celtic Triskele
24	chemical formula: H_2O	:	symbolized glass of water	=	chemical formula: NaCl	:	?	melting ice cube	petrol pump	symbolized jug of beer	diamond	**salt shaker**
25	Rod of Asclepius	:	stethoscope	=	Lady Justice	:	?	firefighter helmet	microscope	blackboard	**judge's gavel**	color palette & brush
27	alarm clock	:	sundial	=	pocket calculator	:	?	hourglass	measuring stick	Roberval weighing scale	Abacus	compass (drawing tool)

In a first study these 27 items were (paper and pencil-) administered to 331 trainees of the Austrian police security academies, aged between 18 and 32 years (about 80 percent male, 20 percent female). Although the time limit for the test execution was set to 18 minutes, all groups of testees finished after seven to 13 minutes. This shows, that the test results do not depend on any organizational speed effect. In a second study only the first 24 items were administered to 265 high school students, aged between 16 and 21 years. This time, eight minutes were at the testees disposal, but most of them did not need it.

The data of both studies were used separately for a psychometric analysis according to the Rasch model.

Testing the Rasch model's validness happened in accordance with the state of the art (cf. Kubinger, 2005). Thus, Andersen's Likelihood-ratio test (LRT) was used with several partition criteria for the given overall sample into subsamples (in both studies 1. score: "high-" *vs.* "low-scorers", that is the partition in testees with a high number of solved items *vs.* testees with a low number of solved items; 2. age: trainees up to 23 years *vs.* trainees older than 23 years, in the first study, and in the second study 2. sex: male *vs.* female students; in the first study 3. education: trainees with a compulsory school education *vs.* trainees with a higher school education, and 3. education: students of a regular high school *vs.* students of a vocational high school, in the second study). Given any significant LRT (comparison-wise type-I-risk, $\alpha = .01$ – running three comparisons this meets a study-wise type-I-risk of approximately $\alpha = .03 < \alpha = .05$), items have to be deleted step by step by repeating this model test until it results in non-significance for each partition criterion. Which item will be deleted has to be decided by means of Rasch's graphical model check. If the Rasch model is valid, each item has the same item (difficulty) parameter, regardless of which subsample is used – this is according to the "specific objectivity" of the Rasch model (cf. Scheiblechner, 2009). Therefore, opposing the item parameter estimations of two subsamples in a Cartesian coordinate system would ideally result in dots only lying on a 45° straight line going through the origin. In practice, differences of any item parameter estimation between two subsamples larger than a tenth of the parameters' range indicates model misfit (for this rule of thumb cf. again Kubinger, 2005).

For analyzing the data the R-package eRm (Mair, Hatzinger & Meier, 2010, 2014) was used. This program also offers Rasch's graphical model check with a confidence ellipse for every or selected items due to their standard errors of estimation (cf. Koller, Alexandrowicz & Hatzinger, 2012).

Results

Table 2 summarizes the results of Andersen's Likelihood-ratio test (LRT) with respect to the three partition criteria for the first study. Table 3 does the same for the second study.

Table 2
The Rasch model tests for 27 items of the first draft of the test Culture-referenced Pictographic Analogies (first study). For the applied three criteria of partitioning the overall sample the results of the asymptotically χ^2-distributed Andersen's Likelihood-ratio test statistic (LRT) are given as well as the degrees of freedom (df) and the respective p-value – if any item within a certain subsample is solved either from all testees or from none, then that item is not included, as a consequence of which df is reduced. The results are based on 331 testees.

partition criterion	χ^2	*df*	*p*
score	19.34	17	.309
age	24.55	23	.374
education	26.41	23	.282

Table 3
The Rasch model tests for 24 items of the first draft of the test Culture-referenced Pictographic Analogies (second study). For the applied three criteria of partitioning the overall sample the results of the asymptotically χ^2-distributed Andersen's Likelihood-ratio test statistic (LRT) are given as well as the degrees of freedom (df) and the respective p-value – if any item within a certain subsample is solved either from all testees or from none, then that item is not included, as a consequence of which df is reduced. The results are based on 265 testees.

partition criterion	χ^2	*df*	*p*
score	81.06	22	.000
sex	82.28	22	.000
education	45.53	42	.002

Indeed, in the first study no significant LRT resulted, however all three LRT in the second study did. The graphical model check for the latter with respect to the partition criterion score is shown in Figure 7. There the confidence ellipses for the items 7, 10, and 2 (as well as for item 6, which is, however, not as easy to recognize) reveal a misfit. For the partition criterion sex the situation is similar, however here item 2 shows the worst misfit. That item's difficulty parameter yielded a value of about 2.0 within subsample "low-scores" and a value of almost 3.0 within subsample "high-scorers", meaning in relation to the other items it is much more demanding for "high-scorers" (ordinate) than for "low-scorers" (abscissa). Furthermore (though not illustrated here by a Figure) that item's difficulty parameter yielded within the male subsample a value of about 3.5 and within the female subsample a value of only about 1.75, meaning in relation to the other items it is much more demanding for male than for female testees. Looking at that item shown in Figure 8, it finally reveals a common

problem with item construction, that is when the intended solution of an item is defined rather by the distractors than by the task intrinsically. In the given case of item 2 the essential relation of the Green Dot Symbol (the product manufacturer has contributed to the financing of packaging collection and recycling) and the PET-1 Symbol (identification of such materials that can be recycled in order to facilitate an easier recycling process: polyester fibers, soft drink bottles, food containers) may be difficult to understand for a lot of people even if they know these symbols' meanings; hence they cannot apply a conclusive relation between the following laundry sign and the given answer options. However, some of the testees get to the solution just by association (or by excluding some answer options and all distractors, respectively), as washing machine and tumble drying are somehow related. This might happen to occur with women more often than with men due to some old-fashioned role expectations (images) which makes women more acquainted with laundry symbols in general. This item raises the question: how specific should the necessary knowledge be when a test, which measures *crystallized-figural* reasoning, is constructed? Moreover: the essential relation of (two times) two everyday objects should be neither unambiguous nor too abstract. At any rate, item 2 has been deleted at the first step of further psychometric analyses.

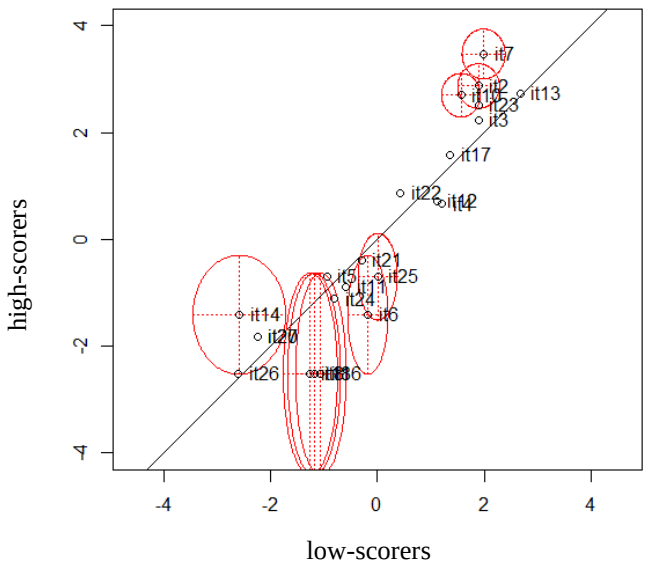

Figure 7

Graphical model check of 23 items of the first draft of the test Culture-referenced Pictographic Analogies – item parameter estimations according to the Rasch model as opposed for "low-" and "high-scorer" (second study). For the items not only the (estimated) item parameters are plotted against each other but also the confidence ellipses are shown which results when the standard error of item parameter estimation is taken into account (α = .01).

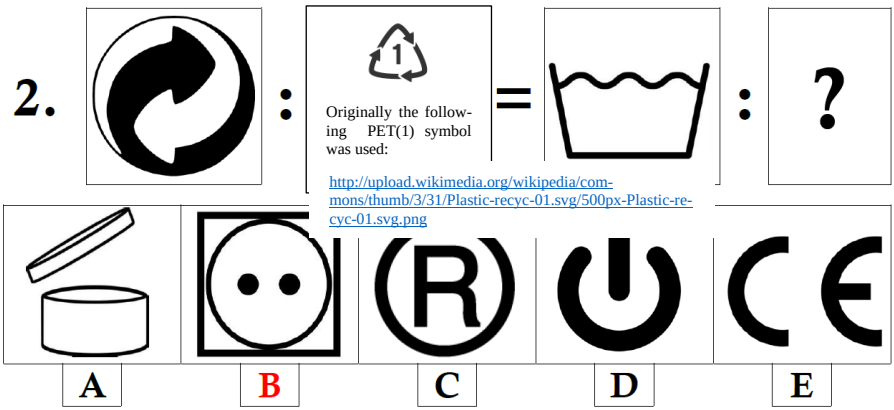

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Figure 8

Item 2 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is B. [Public domain:
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Deleting item 2 still resulted (in the secondary study) in three significant LRTs. Only after further consecutively deleting items 7, 24, 5, and 23, no more significant LRT resulted (cf. Table 4). Item 7 (see Fig. 9) has the same problem where specialized knowledge is necessary in order to solve it. There hardly is any suspicion why this item for instance was relatively easier for "low-scorers" than for "high-scorers" (as already recognizable in Fig. 7), apart from the fact, that the correct answer (C) has unfortunately the same line thickness as the second object on the left side: While "high-scorers" may interchange the solution with some distractor, "low-scorers" may consider the line thickness as the relevant relation. Item 24, referring to some chemical symbols (not illustrated here by a Figure but cf. in Tab. 1) proves to be relatively easier for men than for women. That again puts into question which topics and contents are actually widely relevant to everyday life. The misfit of item 5 (not illustrated here by a Figure but cf. in Tab. 1) can, retrospectively, probably best be explained as follows: the reference to the technological status 20-30 years ago is nowadays of no relevance – and therefore misses the point of *crystallized* reasoning based on everyday objects. Finally, item 23 (not illustrated here by a Figure but cf. in Tab. 1) also demands very specialized knowledge.

Table 4

The Rasch model tests for the remaining 19 items of the first draft of the test Culture-referenced Pictographic Analogies (second study). For the applied three criteria of partitioning the overall sample the results of the asymptotically χ^2-distributed Andersen's Likelihood-ratio test statistic (LRT) are given as well as the degrees of freedom (df) and the respective p-value – if any item within a certain subsample is solved either from all testees or from none, that item is not included, as a consequence of which df is reduced. The results are based on 265 testees.

partition criterion	χ^2	*df*	*p*
score	17.06	14	.253
sex	32.22	17	.014
education	26.07	17	.073

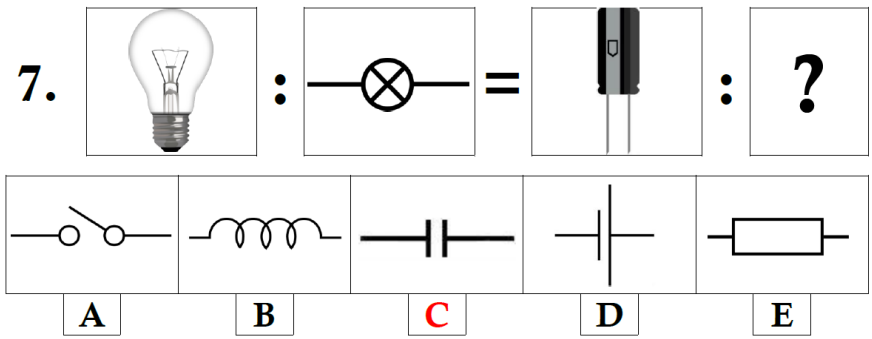

Figure 9

Item 7 of the first draft of the test Culture-referenced Pictographic Analogies. The solution is C. [Public domain: http://openclipart.org/image/800px/svg_to_png/84931/Resin_identification_code.png

To summarize, 5 of 24 items had to be deleted in the second study, in order to get the suggested test conceptualization conforming with the Rasch model. That means a deletion rate of 20.8 percent, which is quite larger than the commonly tolerable rate of 10 percent (cf. Kubinger & Draxler, 2007).

Discussion

While the conceptualization of *Culture-referenced Pictographic Analogies* stood in the first study completely the test, the second study disclosed severe problems of item construction. Of course, the clearly contradictory results may eventually be attributed to different populations of testees, one being eager to master the test, the other working at the test just because of being somehow forced to; nevertheless, the problems are obvious. The items for which the Rasch model do not hold (and maybe some more, too) illustrate that the item topics and contents for the first draft have been chosen rather arbitrarily but not according to some operational definition of the aimed-for ability – apart from the evidence of missing carefulness or attention to the chosen objects' concrete realization (cf. the line thickness in item 7, which induce a relevant relation of the second object on the left side and a certain distractor).

As already indicated, in the first instant the tasks of a test *Culture-referenced Pictographic Analogies* should not refer to highly specialized knowledge, but actually to "everyday" knowledge. That is, it should not test the level of general education (e.g. in the sense of a humanistic education), but deductive thinking (i.e. reasoning) by means of objects that are commonly present nowadays. In the second instant the tasks should focus on everyday objects' common functions but should not be reduced on associating one object to another. Moreover, the best would be to determine the solution not only by the offered answer options (cf. item 4, where according to "Einstein" any other well-known physician is asked, but not automatically (Steven) Hawking).

To this end, it seems appropriate to provide an operational definition of the ability the items of a future test *Culture-referenced Pictographic Analogies* should measure:

It is about the ability to realize simple everyday objects' common functions and to apply them appropriately – and this in a figural manner.

Of course, that definition does not solve the problem of choosing the items' topics and contents. Perhaps lists of the most frequently used nouns in written texts could be helpful[1]. It might also be beneficial to start the other way round, that is to look first for respective functions and then for pairs of objects fulfilling them.

Although a test *Culture-referenced Pictographic Analogies* needs some fundamental revision of the suggested first draft it seems already worthwhile to analyze if *crystallized-figural* reasoning as aimed to be measured by this test actually constitutes a specific intelligence factor but is not just covered by other factors or even by a general reasoning factor. The respective analysis is given by Kubinger (2023b).

[1] e.g.: https://www1.udel.edu/LLL/language/deutsch/top10000.pdf

References

Koller, I., Alexandrowicz, R., & Hatzinger, R. (2012). Das Rasch-Modell in der Praxis – Eine Einführung in eRm [The Rasch model in practice – an introduction in eRm]. Vienna: facultas (UTB).

Kubinger, K. D. (2005). Psychological Test Calibration using the Rasch Model - Some Critical Suggestions on Traditional Approaches. *International Journal of Testing*, *5*, 377-394.

Kubinger, K. D. (2014). Gutachten zur Erstellung „gerichtsfester" Multiple-Choice-Prüfungsaufgaben [Expert report: How to construct multiple-choice examination tasks to stand up in court]. *Psychologische Rundschau*, *65*, 169-178.

Kubinger, K. D. (2023a). Guest Editorial: Promising reasoning test ideas not yet published. Special issue: *Promising reasoning test ideas not yet published. Psychological Test and Assessment Modeling*, *65*, 315-320.

Kubinger, K. D. (2023b). On the dimensionality of Reasoning. *Psychological Test and Assessment Modeling*, *65*, 437-447.

Kubinger, K. D. & Draxler, C. (2007). Probleme bei der Testkonstruktion nach dem Rasch-Modell [Problematic issues when calibrating a psychological test according to the Rasch model]. *Diagnostica*, *53*, 131-143.

Mair, P., Hatzinger, R. & Maier, M. (2010). eRm: Extended Rasch Modeling. http://cran.r-project.org/web/packages/eRm/eRm.pdf [07.07.2012]

Mair, P., Hatzinger, R., & Maier, M. J. (2014). eRm: Extended Rasch Modeling (R package version 0.15-4). Retrieved from http://erm.r-forge.r-project.org/

Scheiblechner, H. H. (2009). Rasch and pseudo-Rasch models: suitableness for practical test applications. *Psychology Science Quarterly*, *51*, 181-194.