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ORIGINAL ARTICLE

Subjective measures of unconscious knowledge of concepts

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Abstract This paper considers different subjective measures of conscious and unconscious knowledge in a concept formation paradigm. In particular, free verbal reports are compared with two subjective measures, the zero-correlation and the guessing criteria, based on trial-by-trial confidence ratings (a type of on-line verbal report). Despite the fact that free verbal reports are frequently dismissed as being insensitive measures of conscious knowledge, a considerable bulk of research on implicit learning has traditionally relied on this measure of consciousness, because it is widely regarded as almost self-evident that the content of any conscious state that is intentional and conceptual can be expressed verbally. However, we found that the most recently developed subjective measures based on trial-by-trial confidence ratings provided a more sensitive measure of conscious and unconscious knowledge than free verbal reports. In a complementary way, the qualitative pattern of the free report and the confidence measures were similar, providing further evidence for the validity of the latter.

Keywords Metaknowledge criteria · Verbal reports · Implicit knowledge · Explicit knowledge · Consciousness · Subjective measures · Concepts

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1 Introduction

Many studies have shown that implicit learning results in knowledge that is difficult to express verbally. It is therefore sometimes concluded that the knowledge is unconscious (e.g., Berry and Broadbent 1984, Lewicki et al. 1988, Reber1967). However, free verbal reports have been thought of as an unreliable source of evidence of conscious or explicit knowledge (e.g., Berry and Dienes 1993, Shanks and St. John 1994). This research attempts to shed more light on this controversy as well as on the usefulness of subjective measures as measures of conscious awareness by comparing free verbal reports with two other subjective measures of consciousness that are based on confidence ratings. To do so, the present research uses one of the tasks that researchers have used to study implicit learning, namely a category learning task.

Implicit category learning is assumed to occur when learning proceeds in the possible absence of any intention to learn and in such a way that people acquire knowledge they are not fully conscious of and, thus, cannot express verbally (e.g., Frick and Lee 1995, Posner and Keele 1968, Reber 1967, 1976). The term ‘‘implicit’’ is commonly used to refer to implicit memory (e.g., Bowers and Schacter 1990, Schacter 1987, Schacter et al. 1989). According to Graf and Schacter (1985, p. 501), ‘‘implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection of previous experiences’’. Thus, implicit memory refers to the influence that a previous event has on performance without one being consciously aware of the influential event. By contrast, implicit learning refers to the acquisition of knowledge about the structural relations among stimuli, without being conscious of that knowledge (see Berry and Dienes 1991, Dienes and Perner 1999, and Seger 1994 for relations between the two research areas). The term ‘‘implicit learning’’ was introduced by Reber (1967). He asked subjects to memorize strings of letters, where, unbeknownst to subjects, the order of letters within the string was constrained by a complex set of rules (i.e., an artificial grammar). After a few minutes of memorizing strings, the subjects were told about the existence of the rules (but not what they were) and asked to classify new strings as obeying the rules or not. Reber (see Reber 1993 for a review of his work) found that subjects could classify new strings 60–70% correctly on average, while finding it difficult to say what the rules were that guided their performance. He argued the knowledge was unconscious.

Over the years, there has been considerable debate about the unconsciousness or implicitness of knowledge with some researchers even questioning the usefulness of an explicit/implicit distinction (e.g., Dulany 2003, Shanks and St. John 1994, Tunney and Shanks 2003). In an attempt to resolve this controversy, researchers have proposed several different criteria of the unconsciousness of knowledge.

One such criterion is the inaccessibility of knowledge to free report. However, starting with Dulany et al. (1984), critics have been unhappy with free report as an indicator of unconscious knowledge. Free report gives the

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subject the option of not stating some knowledge if they choose not to (by virtue of not being certain enough of it); and if the free report is requested some time after the decision, the subject might momentarily forget some of the bits of knowledge they brought to bear on the task (Berry and Dienes 1993). Even if people cannot recall a piece of knowledge in a given period of time, they may be able to recall it later on, if they are given a second chance (Erdelyi and Becker 1974). Similarly, Shanks and St. John (1994) argued that participants' inability to report the rules of an artificial grammar, for example, is not evidence of implicit or unconscious knowledge. Instead, it may be that knowledge is accessible to consciousness, but has to be specifically asked for to be elicited. What the subject freely reports depends on what sort of response the subject thinks the experimenter wants. For example, if the subject classified on the basis of similarity to memorized exemplars, but thinks the experimenter wants to hear about rules, then free reports may not be very informative accounts of the subject's conscious knowledge. That is, a test must tap the knowledge that was in fact responsible for any changes in performance (the *information criterion* of Shanks and St. John, and the problem of *correlated hypotheses* highlighted by Dulany 1968). One way around the information criterion is to use confidence ratings, because then the experimenter does not need to know exactly what the knowledge is that participants use. Any knowledge the participant is conscious of using, no matter what its content, should be reflected in the participant's confidence. This is a major benefit of the use of confidence measures of conscious knowledge.

Chan (1992) elicited a confidence rating in each classification decision, and showed subjects were no more confident in correct than incorrect decisions. Dienes et al. (1995), Dienes and Altmann (1997), Allwood et al. (2000), Channon et al. (2002), Tunney and Altmann (2001), and Dienes and Perner (2003) replicated these results, finding some conditions under which there was no within-subject relationship between confidence and accuracy. Subjects could not discriminate between mental states providing knowledge and those just corresponding to guessing; hence, the mental states were unconscious. Kelly et al. (2001), and Newell and Bright (2002) used the same lack of relationship between confidence and accuracy to argue for the use of unconscious knowledge in other learning paradigms. The method has an advantage over free report in that low confidence is no longer a means by which relevant conscious knowledge is excluded from measurement; rather the confidence itself becomes the object of study and can be directly assessed on every trial.

Dienes and Berry (1997) urged the use of trial-by-trial confidence ratings in measuring conscious and unconscious knowledge. Such measures, along with free report, are called subjective measures because they measure what states of knowledge the subject thinks he or she is in. By these measures, people's knowledge is said to be unconscious when they lack metaknowledge. That is, unconscious knowledge is defined as being in an occurrent knowledge state one does not know one is in (Cheesman and Merikle 1984, Pierce and Jastrow 1884).

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If one knew one was in a certain knowledge state one could express that knowledge on a forced choice test on the content of that knowledge (a so-called direct test). So sometimes people measure conscious knowledge by the use of a forced choice test about the state of affairs in the world that the knowledge is about. Such tests are called objective tests; they are about objective worldly affairs. Failure on an objective test indicates the person does not have conscious knowledge (so if, in addition, an indirect test, e.g., a liking rating, indicated the person had knowledge, we could conclude that the knowledge was unconscious, cf. Kuhn and Dienes 2006). However, passing a test about states of affairs in the world can be achieved not only by conscious knowledge, but also by unconscious knowledge about the world. Indeed, it is sometimes difficult to see why unconscious knowledge should not apply when objective tests are used. Subjective tests are tests about the subjective state the participant is in; that is, they directly test whether the participant is aware of the knowledge state they may be in. Subjective tests assess the presence or absence of conscious knowledge more directly than objective tests do, and can be used when objective tests indicate the participant has some (conscious or unconscious) knowledge.

In the present research, we will compare the free verbal report with two other subjective criteria: The zero-correlation and guessing criteria. The "zero correlation criterion" is a short hand expression for the "zero confidence-accuracy relationship criterion" (Dienes and Berry 1997). When the subject makes a judgment, ask the subject to distinguish between guessing and different degrees of knowing. If the judgment expresses conscious knowledge, on those cases when it is knowledge and not guessing, then the subject should give a higher confidence rating when she actually knows the answer and a lower confidence rating when she is just guessing. In other words, conscious knowledge would prima facie be revealed by a relationship or correlation between confidence and accuracy, and unconscious knowledge by no correlation (the person does not know when she is guessing and when she is applying knowledge). The other subjective measure of unconscious knowledge we will use is the *guessing criterion* (Dienes et al. 1995; see also Dienes and Berry 1997). In order to estimate unconscious knowledge in terms of the guessing criterion, we take all the cases where a person says they are guessing, and examine whether they are actually demonstrating the acquisition of some knowledge, that is whether the percentage of guesses that are correct is greater than a chance level. This is the criterion that is satisfied in cases of blindsight (Weiskrantz 1986, 1997). The person insists they are just guessing, but they can be discriminating up to 90–100% correct. So, based on the guessing criterion, the knowledge in blindsight is unconscious.

It is very difficult to obtain measures that are sensitive only to conscious or only to unconscious knowledge (Merikle and Reingold 1991). An advantage of the combination of the two metaknowledge criteria, the zero correlation and guessing criteria, is that they allow for a measured mix of implicit and explicit knowledge in any one experimental condition (cf. Jacoby 1991). In particular, a percentage of correct guesses that is found to be reliably greater

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than chance in the guessing criterion analysis provides evidence of implicit knowledge without, however, excluding the possibility that explicit knowledge might exist on other trials. By contrast, a zero-correlation criterion analysis that results in reliably greater confidence for correct than for incorrect responses indicates the presence of some explicit knowledge without ruling out the possibility that some implicit knowledge might exist on the same trials. A lack of metaknowledge may be related to people's inability to report verbally what they have learned, because people who lack metaknowledge may not know what specific questions to ask themselves to elicit their own knowledge (Dienes and Berry 1997). We will investigate whether the zero correlation and guessing criteria are more sensitive measures of conscious and unconscious knowledge than verbal reports, and thus whether they alleviate the insensitivity problem of free reports. Free reports have sufficient face validity as measures of conscious knowledge, that for a long time they were the only measure of conscious knowledge, from Smoke (1932) to Reber (e.g., 1967) and Lewicki (e.g., 1986). Given the face validity of free reports, we will explore whether the other subjective measures (i.e., the metaknowledge measures) produce qualitatively similar patterns of results as free reports, which would provide converging evidence for the metaknowledge measures' validity.

One might argue that the guessing criterion faces the same response bias problem as do verbal reports. For instance, a person may say they are guessing when they actually have some awareness of their knowledge (e.g., Merikle and Reingold 1992). It should be noted that, in the present study, participants were clearly instructed that a guess meant their response was based on no information whatsoever. However, a direct way of testing the sensitivity of the guessing criterion is to show that the measure provides the pattern of results expected by a theory of conscious and unconscious knowledge. According to the well-known theory that the acquisition of conscious knowledge requires the use of working memory, a working memory secondary task would be expected to interfere with the acquisition of conscious knowledge while leaving the acquisition of unconscious knowledge unaffected. Such a finding would provide evidence for the validity of the subjective measures (Dienes 2004). Therefore, we will use the dual-task methodology as a means of testing the validity of the subjective measures.

Implicit learning of concepts has mostly been studied using meaningless and highly artificial material, such as dot patterns, or artificial grammars. However, as Whittlesea (1987) argues, the use of highly artificial and arbitrary stimuli in concept formation studies is not informative about the formation of natural concepts. Thus, the present research used stimuli that were more similar to real categories and, therefore, more appropriate for studying natural category learning than highly arbitrary stimuli devoid of any meaning. Moreover, the present stimuli allow one to test the interaction of prior knowledge with empirical learning, which, as the recent view of concepts argues, characterizes the learning of concepts in the real world (see, e.g., Medin 1989, Murphy and Medin 1985, Heit 1994, 1997). Further, as Mathews

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and Cochran (1998) have pointed out, a disadvantage of implicit tasks that use meaningless and highly artificial stimuli is that they are rather boring, tiresome and detached from people's interests.

We will use data on concept learning from E. Ziori and Z. Dienes (submitted). In their experiments, half the participants learned the categories under a dual-task condition thought to discourage explicit learning (see, e.g., Roberts and MacLeod 1995, Jiménez and Méndez 1999, Waldron and Ashby 2001; contrast Shanks and Channon 2002), whereas the other half of participants learned the categories under a single-task condition meant to favor explicit learning.

E. Ziori and Z. Dienes (submitted) used Murphy and Allopenna's (1994) concept learning paradigm, which revealed a strong facilitative effect of prior knowledge on concept learning. The main aim of Ziori and Dienes' study was to investigate the relationship of this effect with implicit and explicit concept learning. During training, participants classified category exemplars with feedback. All exemplars consisted of descriptions taken from familiar everyday domains (i.e., animals, vehicles, and buildings). However, in one condition, the features were meaningful but completely unrelated to each other, whereas in the other condition, the same features were combined such that they were interrelated and integrated by prior knowledge. In a test phase that followed training, all participants had to categorize only the individual features of the category exemplars without feedback, and with confidence ratings given on each trial. Finally, participants had to freely report which features went with which category.

The aim of this article was to compare the guessing and zero correlation criteria with free report. With respect to free report, a high correlation between the knowledge expressed in these reports and participants' knowledge in the test phase would provide evidence of explicit knowledge, since both estimates would be measures of the same knowledge. By contrast, a lack of relationship between the knowledge expressed in the free reports and the knowledge measured in the test phase would indicate the presence of implicit knowledge. As mentioned above, the secondary task was used to test the validity of the subjective measures. If the current subjective measures were valid measures of unconscious knowledge, then we would expect the concurrent task to interfere only with explicit and not with implicit knowledge.

With respect to the effect of prior knowledge on implicit and explicit knowledge, we could not make any clear predictions as to whether prior knowledge would affect one or both types of knowledge. Some researchers (e.g., Hayes and Broadbent 1988) argue that implicit learning is an unselective and passive process of learning with no room for any interpretive processes based on declarative knowledge. On the other hand, it has been suggested (e.g., Frick and Lee 1995, Pothos 2005, Sun et al. 2001, Sun 2000) that implicit learning may interact with prior knowledge and expectations. For example, Pothos (2005, Experiment 2) showed that explicit expectations about stimulus structure facilitated the acquisition of implicit knowledge when the types of information on which the expectations and the knowledge acquired in an

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implicit learning task (i.e., an AGL task) were likely to be the same (see also, e.g., Cleeremans 1993, Dienes and Fahey 1995, and Mathews et al. 1989 for evidence of a synergy between explicit and implicit knowledge). People may direct their attention towards the features or themes highlighted by prior knowledge (see, e.g., Murphy and Wisniewski 1989, Pazzani 1991, Wisniewski 1995) facilitating the acquisition of both explicit knowledge (through analytic, rule-based learning) and implicit knowledge (through, e.g., exemplar-based or associative learning).

2 Method

2.1 Participants

A total of 96 students from the University of Sussex participated in the experiment for payment. Each participant was randomly assigned to one of the four conditions.

2.2 Stimuli

The categories of this experiment were the same as the ones used by Murphy and Allopenna (1994). During learning, participants in the Coherent and the Incoherent condition had to learn a pair of categories consisting of short phrases, such as ‘‘Lives in groups’’ and ‘‘Drives in jungles’’. Table 1 presents an example of the structure of the category exemplars in the two knowledge conditions.

Each participant learned only one out of three category pairs that were constructed for each knowledge condition. In particular, all categories were

Table 1 Examples of the structure of the category exemplars in the two knowledge groups

Category 1 (Characteristic features)	Random features	Category 2 (Characteristic features)
Incoherent condition		
Lives alone	–	Lives in groups
Made in Africa	Four door, two door	Made in Norway
Fish kept there as pets	Hibernates, doesn’t hibernate	Birds kept there as pets
Has a barbed tail	Victorian furniture, modern furniture	Has a furry tail
Thick heavy walls	–	Thin light walls
Convertible	–	Non-convertible
Coherent condition		
Made in Africa	–	Made in Norway
Lightly insulated	Four door, two door	Heavily insulated
Green	Uses gasoline, uses diesel	White
Drives in jungles	License plate in front,	Drives on glaciers
Has wheels	License plate in back	Has treads
Convertible	–	Non-convertible

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constructed from the same features derived from three domains (i.e., animals, buildings, and vehicles). In the Coherent condition, however, the features were interrelated, since they were all taken from the same domain and were thus expected to activate participants' general knowledge of that domain. For example, in this condition, the category exemplars contained features from the domain of vehicles, such as "Drives in jungles" and "Made in Africa" in one category and "Drives on glaciers" and "Made in Norway" in the other category. By contrast, in the Incoherent condition, the features were unrelated to each other since they were arbitrarily taken from all three domains. Thus, the incoherent categories contained features, such as "Thick heavy walls" and "Lives alone" in one category and "Thin light walls" and "Lives in groups" in the other category.

Apart from the features, the category pairs in the two knowledge conditions also shared the same structure. Each pair was constructed from six binary stimulus dimensions that always appeared in a specific category and were called *characteristic*, and three binary dimensions that appeared about equally often in the two categories and were called *random*. The category learning phase used 22 exemplars, each of which contained 3 characteristic features and 2 random ones. Training stopped when all participants saw a fixed number of exemplars (see E. Ziori and Z. Dienes, submitted).

Thirty-six single-feature exemplars (i.e., 24 characteristic-feature exemplars and 12 random-feature exemplars) were constructed for the test phase. Each feature of the binary stimulus dimensions was tested twice to increase the sensitivity of analyses (see E. Ziori and Z. Dienes, submitted, and Experiment 2, Murphy and Allopenna 1994, for more details about stimuli construction). Performance in this phase was measured in terms of accuracy only on the characteristic features.

2.3 Procedure

During training, each participant saw category exemplars presented one at a time on a computer screen. Participants had to indicate whether each of these exemplars belonged to Category 1 or Category 2 and give their confidence rating for each response on a scale from 50 (complete guessing) up to 100 (complete certainty) within a time limit of 7 s. Any response that exceeded this time limit was considered as missed trial. Participants allocated to the Dual-task condition had to perform another task while categorizing the exemplars, which was expected to interfere only with explicit learning and not with implicit learning (see E. Ziori and Z. Dienes, submitted; see also Hitch and Baddeley 1976, and Roberts and MacLeod 1995). In particular, prior to each category exemplar, participants in this condition saw a six-digit string (containing the digits 1–9 presented in a random order), which they had to repeat aloud throughout the categorization of each exemplar. At the end of each trial (i.e., after each response on the category learning task and the feedback that was provided), they were shown a second string and had to decide whether the two strings were exactly the same or not. Feedback about

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participants' accuracy on the secondary task was provided immediately after each response.

Training was followed by a test phase, in which all participants had to categorize the single-feature exemplars as quickly and accurately as possible, and provide their confidence rating for each response. The order in which each participant saw the test exemplars was randomized. Participants were not shown the correct response, and did not perform the secondary task during this phase. At the end of the experiment, all participants were asked to report as many features as they could, and indicate the category they thought each feature belonged to.

3 Results

3.1 Categorization performance

Performance in the test phase was measured in terms of participants' percentage of correct responses on the characteristic features. A 2×2 (Prior knowledge [Coherent vs. Incoherent] by Task load type [Single vs. Secondary]) ANOVA on the percentage of correct responses revealed a significant effect of Prior knowledge, $F(1,92)=37.18$, $P<0.001$, $MSE=310.69$, establishing the expected advantage of the Coherent over the Incoherent group ($M=77\%$, $SD=20$ vs. $M=55\%$, $SD=17$). Moreover, the secondary task impaired participants' ability to categorize the single-feature items, $F(1,92)=12.27$, $P=0.001$, $MSE=310.69$ ($M=73\%$, $SD=19$ in the Single-task condition vs. $M=60\%$, $SD=22$ in the Dual-task condition). The interaction of the two variables was not reliable ($P=0.648$).

3.2 Confidence ratings

Participants' explicit knowledge in terms of the zero-correlation criterion was measured by estimating the difference between confidence for correct responses and confidence for incorrect responses for all the characteristic features. (Nine participants who gave no incorrect responses at all were excluded).

As shown in Table 2, the Coherent group had a greater difference in confidence between correct and incorrect responses than the Incoherent group (16.5 vs. 7.9), $F(1,83)=9.16$, $P=0.003$, $MSE=160.74$. Thus, Prior knowledge increased the amount of explicit knowledge. Moreover, participants in the Dual-task condition had a smaller difference in confidence between correct and incorrect responses than participants in the Single-task condition (6.0 vs. 17.5), $F(1,83)=16.86$, $P<0.001$, $MSE=160.74$. That is, the secondary task interfered with explicit knowledge, as expected. However, evidence of explicit knowledge was found in both the Incoherent condition, $t(46)=4.36$, $P<0.001$, $SE=1.80$, and the Dual-task condition, $t(42)=3.43$, $P=0.001$, $SE=1.76$, in which the mean values of explicit knowledge were greater than zero. Similarly, the

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Table 2 The mean values of metaknowledge in the test phase as measured by the zero-correlation and the guessing criteria

Metaknowledge criteria	Knowledge types	Task load types	Confidence			
			Difference	*M*	*N*	*SD*
Zero-correlation (conf. when correct−conf. when incorrect)	Incoherent	Single	73.3−59.9	13.5	23	13.7
		Secondary	65.9−63.4	2.5	24	8.0
		Total	69.5−61.7	7.9	47	12.4
	Coherent	Single	83.4−61.5	21.9	21	14.7
		Secondary	74.6−64.1	10.5	19	13.7
		Total	79.2−62.7	16.5	40	15.2
	Total	Single	78.2−60.7	17.5	44	14.7
		Secondary	69.7−63.7	6.0	43	11.5
Guessing (percentage of correct guesses)	Incoherent	Single	–	48.2	22	30.4
		Secondary	–	49.2	22	27.0
		Total	–	48.7	44	28.4
	Coherent	Single	–	54.4	19	32.4
		Secondary	–	69.2	18	21.4
		Total	–	61.6	37	28.2
	Total	Single	–	51.0	41	31.1
		Secondary	–	58.2	40	26.4

overall mean value of explicit knowledge was reliably greater than zero, $t(86)=7.69$, $P<0.001$, $SE=1.54$. The interaction of the two variables was not reliable ($P>0.9$).

The percentage of guess responses that were correct was analyzed to measure participants' implicit knowledge of the individual features in terms of the guessing criterion. (Fifteen participants who did not guess at all were excluded from this analysis). As shown in Table 2, the Coherent group was significantly more accurate when they thought they were guessing than the Incoherent group (61.6% vs. 48.7%), $F(1,77)=4.34$, $P=0.041$, $MSE=796.94$. Moreover, the percentage of correct guesses in the Coherent condition was significantly greater than chance, $t(36)=2.50$, $P=0.017$, $SE=4.64$, providing evidence of implicit knowledge in that condition. By contrast, the corresponding percentage in the Incoherent was not significantly different from chance ($P=0.760$). Further, the overall percentage of guesses that were correct (54.6%) was not reliably greater than chance, $t(80)=1.43$, $P=0.157$. Thus, evidence of implicit knowledge of the individual features was found only when participants were aided by prior knowledge. The effect of Task load and its interaction with Prior knowledge were not reliable ($P>0.2$).

3.3 Verbal reports

To examine how well verbal reports explained the results of the test phase, the following measure of estimating the relation of participants' performance with their verbal reports was used: The predicted percentage of correct classification that participants could have achieved in their verbal reports if they had reported and classified all 12 characteristic features was compared with their

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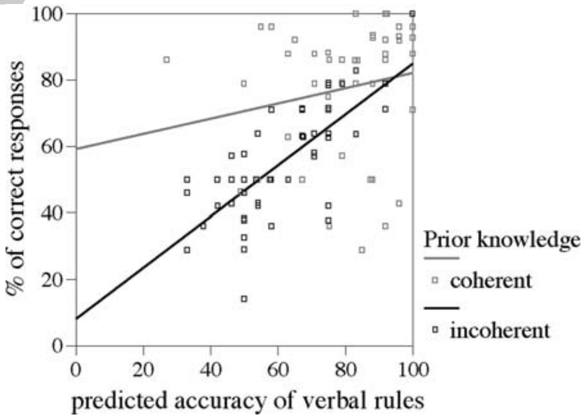
actual percentage of correct classification in the test phase in which they classified all 12 characteristic features. It should be recalled that, at the end of the experiment, participants were asked to report as many features as they could remember and categorize them. The predicted percentage of correct classification in the verbal reports was estimated by applying the following rule: The number of characteristic features that each participant mentioned in the verbal reports was subtracted from the total number of the characteristic features that she could have classified if she reported all of them (i.e., 12). The remainder (i.e., the number of features that were not mentioned) was divided by 2 in order to estimate participants' predicted accuracy with a 50% probability of being right. The number of the reported features that were correctly classified was added to the quotient, and this sum was divided by 12 and multiplied by 100 to yield a percentage of correct classification in the verbal reports. For instance, if a participant reported 8 features, 6 of which were classified correctly, her predicted accuracy would be 67% (i.e., 12−8=4, 4/2=2, 6+2=8, 8/12=0.666, 0.67×100=67%). This predicted accuracy in the verbal reports was compared with participants' actual performance in the test phase with a by-subjects regression. If the two measures are highly correlated, it may be concluded that knowledge is explicit, since both estimates are measures of the same knowledge. By contrast, if they are not related to each other, then this is evidence that knowledge is implicit.

The scatter plot in Fig. 1 showed r=0.186 with a slope of 0.228 and an intercept of 59.3 for the Coherent group, and r=0.732 with a slope of 0.769 and an intercept of 8.2 for the Incoherent group. Following Dulany et al. (1984), if the slope does not differ significantly from 1, this provides evidence of conscious knowledge, since in that case, the verbal rules would predict participants' performance without significant residual. A t test showed that the slope of the regression line in the Coherent condition was significantly different from 1, $t(46)=-4.34$, $P<0.001$. Moreover, the slope for the Coherent group was not significantly different from zero, $t(46)=1.28$, $P=0.206$, which means that there was no detectable linear relationship between verbal reports and the

Fig. 1 Percentage correct classification of the individual features against predicted accuracy of verbal rules in the two knowledge conditions



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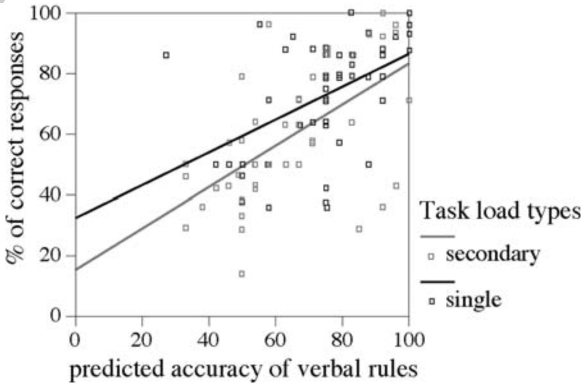
percentage correct categorization in the test phase. By contrast, the slope in the Incoherent condition differed significantly from zero, $t(46)=7.29$, $P<0.001$, which shows that a linear relationship between participants' verbal reports and performance in the test phase was evident only in the Incoherent condition. The slope of the Incoherent group differed significantly from 1 too, $t(46)=-2.2$, $P<0.05$. The slopes of the Coherent and the Incoherent groups differed significantly, $t(92)=2.62$, $P<0.02$. In line with the guessing criterion, which showed that the Coherent group acquired unconscious knowledge, the verbal reports showed that only the Coherent group's verbal rules could not predict their performance in the test phase (i.e., that there was no linear relationship between verbal reports and percentage correct categorization). Unlike the zero-correlation criterion, however, which showed that the Coherent group acquired some conscious knowledge, the verbal reports measure found no evidence of conscious knowledge in the Coherent condition.

The scatter plot in Fig. 2 shows $r=0.590$ with a slope of 0.678 and an intercept of 15.3 for the Dual-task condition, and $r=0.473$ with a slope of 0.541 and an intercept of 32.3 for the Single-task condition. The slope of the Dual-task condition differed significantly both from zero, $t(46)=4.96$, $P<0.001$, and from 1, $t(46)=-2.35$, $P<0.05$. Similarly, in the Single-task condition, the slope was significantly different from zero, $t(46)=3.64$, $P=0.001$, as well as from 1, $t(46)=-3.08$, $P<0.01$. Moreover, the slopes of the two Task load conditions did not differ significantly, $t(92)=0.68$, $P>0.40$, contrary to the prediction that the secondary task would interfere with the acquisition of explicit knowledge as well as to the results of the zero-correlation criterion, which showed that the secondary task reduced the amount of explicit knowledge.

4 Discussion

The present research compared participants' verbal reports with two other subjective measures of conscious and unconscious knowledge (i.e., the zero-correlation criterion and the guessing criterion) in order to determine whether

Fig. 2 Percentage correct classification of the individual features against predicted accuracy of verbal rules in the two task load conditions



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the confidence-based measures were more sensitive than free report. As already mentioned, free reports are frequently criticized on the basis that they may exclude low-confidence knowledge (e.g., Dienes and Berry 1997, Shanks and St. John 1994). A potential solution to this problem is the use of subjective measures that are based on participants' confidence ratings. If the results of the free reports' analyses converged with the results of such subjective measures, it could be inferred that both subjective measures are equally sensitive and valid measures of conscious awareness. The present results showed that the measures that were based on participants' confidence ratings were more sensitive than measures relying on simple free report.

An important finding that supports the construct validity of the zero-correlation and the guessing criteria is the effect of the secondary task on the acquisition of explicit knowledge. In line with the prediction that the secondary task would interfere with explicit learning (e.g., Roberts and MacLeod 1995, Waldron and Ashby 2001), the secondary task did not affect the amount of implicit knowledge as measured by the guessing criterion but did reduce the amount of explicit knowledge as measured by the zero-correlation criterion. By contrast, the secondary task had no effect on the acquisition of conscious knowledge as measured by the verbal reports. That is, the measures based on confidence ratings were more sensitive than the free reports in detecting the expected detrimental effect of secondary tasks on conscious knowledge. Moreover, the above pattern of results weakens the argument that the guessing criterion, as used in this concept learning paradigm, suffers a response bias problem; that is, percent correct when guessing most likely does track unconscious knowledge. M. Twymann and Z. Dienes (submitted) also found that response bias was not a problem for the guessing criterion using stimuli common in the artificial grammar learning literature; participants urged to use guess responses less often were not able to assign a higher confidence rating to responses specifically likely to be correct.

The coherent group acquired both implicit and explicit knowledge as shown by the guessing criterion and the zero-correlation criterion respectively. The acquisition of implicit knowledge under the coherent condition may be explained in terms of the fact that, during the training phase, which involved the categorization of exemplars consisting of sets of features, the coherent group may have relied on the overall similarity of whole exemplars to a theme or on implicit memories of prior exemplars of other related categories rather than on individual features (see E. Ziori and Z. Dienes, submitted). By contrast, participants in the incoherent group, who could not rely on either a theme or prior exemplars of other categories, seem to have processed the exemplars analytically relying on feature-category associations or on explicit memories of prior exemplars, which included information about the individual features, rather than on overall similarity relations. However, it is highly unlikely that participants aided by prior knowledge of so familiar domains acquired no conscious knowledge of the category features. After all, in most cases, participants are likely to employ both conscious and unconscious knowledge in any given experimental task. Furthermore, the results of the

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zero-correlation criterion in both the training and the test phases showed that prior knowledge increased the amount of explicit knowledge. Presumably, prior knowledge allowed the coherent group to distinguish between theory-relevant and theory-irrelevant features and pay more attention to the former (see, e.g., Pazzani 1991, Wisniewski 1995; see also Heit 1997).

Thus, the co-existence of explicit and implicit knowledge shown by the zero-correlation and the guessing criteria in the present research provides further support of the use of the two subjective measures as useful measures of conscious and unconscious knowledge. On the other hand, the free reports showed that the coherent group acquired only unconscious knowledge. Accordingly, the free reports proved rather insensitive measures of conscious knowledge, consistent with the criticism that free reports have received (e.g., Dienes and Berry 1993, 1997, Shanks and St. John 1994).

However, several findings did reflect a consistency between the free report measure and the confidence measures which is reassuring in supporting the validity of the zero-correlation and the guessing criteria; if they all measure conscious knowledge to some degree, there should be some convergences. As already mentioned, free reports that would successfully predict categorization performance in the test phase could be taken as evidence of the presence of explicit knowledge, since both measures would be estimates of the same body of knowledge. On the other hand, a lack of relationship between free reports and performance (with either progress in performance only or progress in the verbal reports only) may be indicative of implicit knowledge. The present results showed that such a lack of relationship occurred only in the coherent condition, which also led to the acquisition of implicit knowledge as measured by the guessing criterion. By contrast, in the incoherent condition, in which there was no evidence of implicit knowledge in terms of either of the two confidence measures, the knowledge expressed in the free reports was highly correlated with the knowledge acquired in the test phase. Thus, the consistency of the free reports with the guessing criterion confirms the finding that prior knowledge facilitated the acquisition of implicit knowledge.

The finding that the zero-correlation criterion provided evidence of explicit knowledge (which was greater under the coherent condition) is not surprising, since, as already mentioned, the two subjective criteria of unconsciousness allow the co-existence of implicit and explicit knowledge. In fact, many participants of the coherent group acquired explicit knowledge of the individual features that they could express verbally, as evidenced from the high predicted accuracy of their verbal rules (see Fig. 1). Another possible interpretation of the high predicted accuracy of the verbal rules that some of the participants in the coherent group demonstrated may be that these participants lacked *attitude explicitness* and still had *content explicitness*. According to Dienes and Perner (1996, 1999), full metaknowledge requires two types of explicitness, namely *content explicitness* and *attitude explicitness*. Content explicitness refers to the participant's ability to represent oneself as being in the *possession of propositional content X* (for example, the knowledge that "this is a cat"). Attitude explicitness refers to the participant's ability to represent an

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appropriate attitude towards a given content that, for example, differentiates between knowledge and mere guessing. When subjects know that they know, their representations have attitude explicitness. Accordingly, the zero-correlation and the guessing criteria address only attitude explicitness. Knowledge may be unconscious either when participants' representations lack attitude explicitness or when in addition they lack content explicitness. Thus, when people provide accurate responses in their verbal reports, which they consider as guesses, they may have attitude implicitness and content explicitness. (Of course, when people report accurate knowledge with a certain degree of confidence, then we have a case of both content and attitude explicitness).

As already mentioned, a strong criticism against free reports is that they are not sensitive to all the relevant conscious knowledge that participants have (Shanks and St. John 1994). On the other hand, the fact that free reports as well as subjective criteria (based on participants' reports of the mental states that might have determined their judgments) rely on subjective self-assessments does not necessarily render them unreliable measures of consciousness. After all, conscious awareness is a subjective state (Dienes 2004). Thus, subjective measures can be validated by showing that they behave in ways expected on a theory of conscious and unconscious knowledge. For example, many people a priori expect secondary tasks involving executive or working memory function to interfere with the acquisition or application of conscious knowledge and to a greater extent than unconscious knowledge. Finding that dual-task conditions did decrease the amount of explicit knowledge indicated by the zero correlation criterion but left the guessing criterion unaffected helps to validate those measures. This is exactly the same logic as the process dissociation procedure that Jacoby (1991) proposed as an answer to the contamination problem (i.e., the possibility of direct or explicit tests being contaminated by implicit knowledge and of indirect or implicit tests by explicit knowledge) that plagues the measures of awareness. To do so, the specific procedure uses a dissociation of measured processes to validate the measures of the processes. We have less strong prior conceptions about whether prior knowledge should affect both explicit and implicit knowledge. The finding that prior knowledge helps both types of knowledge, as measured by the zero correlation and guessing criteria, can be taken more seriously given the pattern of results with the secondary tasks.

It should not be concluded that free reports are a completely valueless source of information in implicit learning tasks, despite their relative insensitivity. But free reports can be a useful tool of detecting unconscious knowledge only to the degree that they are used as a complementary measure of conscious knowledge and as a means of testing the validity of other subjective measures.

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