Length overestimation bias as a product of normative pressure arising from anthropocentric vs. geocentric representations of length[1]

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Three exploratory studies examine adjustment of the cognitive system to the change or innovation introduced by the metric system. These studies begin from the supposition that two norms of reference may coexist when non-experts have to estimate the length of a line: The anthropocentric, the more ancient and natural norm, and the geocentric metrical system, the more modern and external to the subject. The fine discrimination provided by the decimal metric system is often unnecessary in daily life, and anthropomorphic measures (the finger, the span, the step) may be sufficient to estimate the length of objects. The newer decimal metric system has not yet displaced the ancient anthropomorphic system, and the coexistence of these two systems, according to circumstances, can be an important source of cognitive bias. The research hypothesis is that, compared to units in the anthropomorphic system, the mm and the cm embody the normative property of being "smaller", a property that may result in a tendency to overestimation in absolute estimations of length. It is also anticipated that the higher the probability of error in a task (e.g., the more mm or cm a line has, or the less precise are the available perceptual cues), the greater the bias towards length overestimation.

> *The whole science of geometry may be said to owe its being to the exorbitant interest which the human mind takes in lines. We cut space up in every direction in order to manufacture them* (William James, 1890/1983; p. 791)

Metric systems used to estimate the size, weight or value of objects, are not yet applied exclusively and universally, and continue to reflect a considerable diversity across human groups, ages and countries. Adoption of a universal metric system constitutes a quite unique innovation process involving introduction of cultural uniformity where diversity prevails.

As social psychology studies of social change and innovation show (Lewin, 1948; Moscovici, 1976; Mugny & Pérez, 1991; Newcomb, 1943; Pérez & Mugny, 1993), social change is seldom an all or nothing affair. Systems of reference are rarely transformed completely in a single step. Before a social change (that entirely replaces an old reference system) is fully completed a gradual conversion process tends to occur (Moscovici, 1985) during which two or more systems of reference norms can coexist (the old and the new) and one or another of these may guide individuals' behaviors and judgments depending on the situation. To change an entire reference system it is necessary to overcome social resistance (cf. Papastamou, 1983; Pérez, Moscovici & Mugny, 1991) – anchored in social comparison processes – and produce a social identity change, as well as cognitive resistance – anchored in validation processes – and produce internalization of the new reference frame (Moscovici, 1980; Moscovici & Personnaz, 1980; Mugny et Pérez, 1991). While this process of conversion to the proposed innovation is in progress, two reference systems may coexist and this can, according to circumstances, be a significant source of cognitive bias.

To return to the universalization of measurement systems, social resistance can be illustrated just by thinking about the political debate recently precipitated by the forthcoming intro-

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duction of the Euro as the common currency in European Union countries. It could be seen, during the recent political discussions, that abandonning national monetary systems by Europeans is not just a matter of mathematical economy to identify the appropriate rates of exchange. The debate also evidently involved arguments about national identity, manifested particularly in the connotations of names. The name Ecu, for instance, was eventually changed to that of Euro and there was also discussion as to whether the smaller units (one hundredth of a Euro) should be called "centimes" (as France proposed) or "cents", the name finally adopted. From a social psychological view this is not surprising when one considers that social differentiation and not just a specific national currency is going to be lost. European parliamentarians are trying to ensure that their own countries are represented symbolically as strongly as possible within the new currency. This may facilitate people's identification with the currency in their respective countries, or may serve to express power over the other countries. All this suggests that the form this change eventually takes will not be determined purely by economic factors. A variety of forms of social psychological resistance may intervene.

The present cross-national diversity of currencies is very similar to the situation obtained for the measurement of length up to 1792 when the Academy of Sciences in Paris proposed that the problem could be resolved by adopting one ten millionth part of the quadrant of the meridian passing through Paris (i. e. one metre) as the universal reference unit for length. A universal measure for length may well have been proposed because of the variety of length standards in use in different countries, regions, and even different guilds. The Babylonian foot, for instance, was approximately equal to 0.3083 metres, the Greek foot 0.30683, the Roman foot 0.2946, the Chi in China 0.3181, the Fod in Denmark 0.314, the fot in Finland 0.297, and the Anglo-Saxon foot 0.3048 meters. One can imagine that this standardisation provoked considerable social dissent and all kinds of conflicts. The new metric system spread only very gradually within and between countries and its adoption was not uniform in all countries, nor it is now. In France, for instance, by 1799 a political meaning had been given to the adoption of the new system which, quite apart from the innovation involved and the rather odd names for the units of the decimal measurement system, could explain its limited acceptance by a considerable proportion of the public, until an edict in 1837 introduced it as the sole and obligatory system. Its institution in other countries spans the period from 1820, when it was adopted in the Benelux countries to the beginning of the XXth century by which time it had been introduced into such countries as China, Denmark, Russia and several South American states.

This slow change process and the slow adoption of the innovation indicates overt political and social resistance, but also cognitive resistance. The proposal of the metre as a universal unit could seem arbitrary. However, it is not very dissimilar to units of measurement employed in every civilization to assess the dimensions of things. Before the metre was introduced, what was common to all units of measurement was the size of adult human body: the inch, the span, the elbow, the foot, the step, the brace (meaning the extension of a man's arms opened and forming a cross). The units of measurement which preceded the metric system were clearly anthropomorphic. Even the rod, the unit closest to a metre, could have had an anthropomorphic origin; it bears a close relationship to the length of the cane customarily used as a walking stick by people in antiquity. Even the mile has an anthropomorphic sense: it was equivalent to 1000 roman steps (about 1851 metres) each of 5 feet, with each foot being about 11.62 inches. The maritime mile, still widely used today, also had an anthropomorphic origin: a maritime mile was the sum of 10 cables, 185.2 metres each. A cable was the sum of 111 braces. The league (about 5572 metres) was a travelling measure, and also indicates the furthest point that could be seen from a village. The word "league" is still used as a name for some districts.

The metre, in contrast, has a geographic origin (the ten millionth part of the quadrant of the meridian) and not an anthropomorphic one. Indeed, it is also true that the measures in use in every country were all less than the 100 centimetres of the metre: the foot, roughly measuring 30 cm; the elbow about 57 cm; the yard 91 cm.; the rod around 85 cm. Only the brace, a measure that fluctuates between 1.62 and 2.13 meters, lies outside this value. But this was mainly used in the navy, where the ancient mile and not the kilometre is still used, as if a small measure wasn't sufficient, and perhaps also because at sea the arms have a more important function than legs. In addition, the smaller anthropomorphic reference unit, the finger, has always measured more than 1 cm, the most comparable unit of measurement in the newer decimal metric system[3].

These comparisons from the natural history of measurement lead us to conclude that the cm and the metre involved the introduction of a metric system that makes finer discriminations than those measurement systems with which civilizations (and probably also individuals) spontaneously endowed themselves, but it also produces a less convenient measuring instrument (i.e. not many people routinely carry a metre rule with which to make measurements). The aim of our work has been to try and study the adjustment of the cognitive system to the change or innovation introduced by the metric system. At a theoretical level we ask to what extent the cognitive system accommodates to an external, non-anthropocentric pattern when the most natural option appears to be an anthropocentric pattern. Several studies on perception assume that anthropomorphism may be a significant referent in structuring perception (cf. Dasi & Pérez, 1993; Pérez, Dasi & Mugny, 1996). Gibson's (1979) ecological approach, Segall, Campbell & Herskovits's (1966) research on the effects of the ecological-cultural context upon illusions, and the works of Michotte (1946) and Heider (1944) could all be cited here. At a more specific level the so-called physiological theories advocate the physiological properties of the human eye (density of retinal receptors, corneal astigmatism, arrangement of eye muscles, etc.) as explanations for some features of visual perception (for example, illusions; for a recent review see Higashiyama, 1996). In a sense it can be said that these theories also incorporate a kind of anthropomorphism in perception. Without taking for granted the necessity of anthropomorphism in the perception process, we do acknowledge the possibility that two systems or two norms of reference (i.e., two standards regularly used by a population to measure length) exist side by side, namely the more ancient and natural anthropocentric norm, and the geocentric norm, more modern and external to the subject. The anthropocentric norm involves exploration of spatial relations with the observer as the reference, while the geocentric norm entails exploration with an instrument more external to the observer.

The fine discriminations possible with the mm and cm units provided by the decimal metric system are hardly necessary for most of us most of the time in our daily lives. We can manage perfectly well with anthropomorphic measures (the finger, the span, the step) and these deal adequately enouh with the dimensions of most objects. Only if one is involved in one of the few professions in which the millimetre is fundamental (technical drawing, architecture, carpentry, etc.) does the decimal metric system become relevant to perception. But in most cases quite a coarse interpretation of the decimal system units is applied, indeed to such a degree that the method of absolute estimates is one of the least used in psychophysical studies of length due to its variability. This is merely another indication that the perceptual system has not yet adapted to the accuracy provided by the decimal metric system. In short, it is quite probable that the new decimal metric system has not yet displaced the older, more natural and more readily available anthropomorphic system.

The research hypothesis is that anthropomorphic and decimal measurement systems presuppose different representations of visible length for the human eye. The finger (around 2 cms) is the smaller unit of measurement in the anthropomorphic system. Conversely in the decimal system the smaller naturally visible unit for the human eye is the mm. Implicitly this latter system induces an overestimation of objects, because with the mm and the cm a pres-

3 The old Egyptian finger, for instance, measured 1.87 centimetres; the Fileterian finger 2.18; the Caldeoasirian finger measured 2.2 centimetres; the Hebraic finger 2.18; the Greek finger 1.93, etc.

sure is created to give greater importance to small differences among objects since these differences can be measured. Compared to units in the anthropomorphic system, the mm and the cm embody the normative property of being "smaller", a property that may be amplified through contrasts in the mental representation of these units of measure, resulting in a shortening (i.e. underestimation) of their objective length. Of course these are psychological effects, the nature of which could also arise from the nature of the decimal metric system as a normative system, one that requires subjects to notice very small diferences in the dimensions of objects.

These observations led us to examine the possible mistakes that occur when estimating small lengths and to see if these mistakes occur more often in one direction than another (i.e., whether they evidence a bias). The hypothesis was that length estimates in cm, and even more so in mm, will show a tendency towards overestimation. The rationale for this hypothesis is an underestimated mental representation of these units, as contrasted with the closest natural or anthropomorphic unit (i.e. the inch). It was also expected that the greater the possibility of error in the task (for example, the more mm or cm a line has; or the more imprecise the perceptual cues available in the situation), the greater will be the bias towards overestimation. The rationale for this hypothesis is that as the requirements of measure precision in a task increase, or the possibility of measurement error in length estimation increases, so the decimal metric system becomes more relevant and subjects will rely more heavily upon their underestimated representations of units in this system.

Study 1

The first study tested the following prediction: if we ask subjects to use millimetres to estimate the length of a given object this will result a greater overestimation of its length than if we ask them to use centimetres. The rationale for this prediction is based on the general hypothesis that an overestimation bias for length arises because of the divergence between the geocentric and the anthropocentric metric systems. The anthropomorphic unit of length closest to the centimetre is the finger which is about 2 cm. Thus the cm is closer to this unit than the mm. It is assumed that the further the geocentric unit is from the anthropocentric reference system, the more difficult it will be for the subject not to make biased estimates, and hence distortion in estimates will be greater. It was predicted that distortion would be in the direction of overestimation of object size because, if the cm is represented mentally with the impression that "it is smaller than normal" – where "normal" corresponds to the bodily referents mentioned – this impression should be maximized when using the mm. We also arrive at this prediction – that the object will be more over-valued using millimetres than using centimetres – from the hypothesis that the smaller the unit measurement employed, the greater the importance that will be given to short parts of the object.

Procedure and design

The experiment was carried out with 32 Spanish undergraduates (14 women; 18 men), each tested individually.

Estimation task. Firstly, subjects were required to indicate the length of three different horizontal lines, one of 4 cm, one of 8 cm and one of 12 cm. We will refer these answers as estimates. These lines were presented one at a time and were drawn with an ordinary felt tip pen on separate Dina-4 sheets (29,5 cm×21 cm). The order of presentation of lines was counterbalanced in the following way: Half of the subjects were first showed the 4 cm line, then the 8 cm and finally the 12 cm; for the other half the order was reversed (12-8-4). The metrical scale to be used (cm *vs* mm) was a between-subjects factor in the experimental design: half the subjects were required to indicate the length of the lines in cm, the other half in mm.

Drawing task. On completion of the length estimation task, subjects were given a 21 cm square sheet and were asked to draw lines of 4, 8 and 12 cm (or lines of 40, 80 and 120 mm, depending on the metrical scale they had been assigned previously). We will refer to these an-

Table 1: Estimations and drawings (in cm) for 4, 8 and 12 cm lines (N = 32). Standard deviation in brackets

	Line of 4 cm				Line of 8 cm				Line of 12 cm			
Estimations	4.58 (1.56)				9.04 (2.25)				14.27 (3.85)			
Orientations for drawings	← 4a	↑ 4b	→ 4c	↓ 4d	← 8a	↑ 8b	→ 8c	↓ 8d	← 12a	↑ 12b	→ 12c	↓ 12d
Drawings	4.17 (1.53)	4.03 (1.16)	4.02 (1.44)	3.81 (1.20)	7.10 (2.01)	6.84 (1.88)	7.28 (1.95)	6.56 (1.89)	10.74 (2.45)	10.45 (2.57)	10.43 (2.53)	9.65 (2.29)
Contrast within drawings				4a: .02 4b: .02 4c: .07	8b: .02	8c: .01		8a: .01 8b: .02 8c: .01				12b: .01 12c: .01 12d: .01
Drawings vs estimations p <	n.s.	n.s.	n.s.	n.s.	.012	.004	.02	.001	.002	.001	.001	.001
Correlations: estimation with drawings (all r are p < .001)	−.68	−.71	−.68	−.70	−.64	−.64	−.74	−.71	−.63	−.55	−.64	−.60

swers as *drawings.* The order of lines for a given subject was the same as that in the previous length estimation task (4-8-12 or 12-8-4). As a control for the direction of drawings subjects were asked to draw each line in four different directions: top-down vertical (↓); bottom-up vertical (↑); left-right horizontal (→) and right-left horizontal (←). A mark (→) and a small dash (|) were drawn three centimetres from the edge of the sheet in order to indicate the starting point from which the line should be drawn. Subjects then were told «Please draw, starting from the dash and in the direction indicated by the arrow, a line that measures… (4, 8, 12 cm or 40, 80, 120 mm, according to the length of line required and the metrical scale condition)». Each subject was asked to follow a particular order in drawing the lines from these different directions, the order being randomised across subjects.

Results

No significant differences were found as a function of whether subjects were asked to perform the task in cm or in mm ($p > .40$). Therefore our hypothesis was not confirmed. However, it may be observed that means for the estimates were always greater than means for the drawn lines (see Table 1). This difference was significant for the 8 and 12 cm lines and for all four directions ($p < .02$). No differences between estimations and drawings reached significance for the 4 cm line. The correlation among drawings and estimations were highly significant and negative in all conditions, even for the 4 cm lines which suggests that the underlying dynamic is the same. The high values of these correlations suggest that any bias which may derive from drawings versus the anchoring of numerical scale implied by cm/mm estimations is minimal. These results indicate that the mental mm/cm applied by subjects is underestimated; this results in the overestimation of length and in underestimation in the drawing of a given length (for similar results, see Dasi & Pérez, 1993; Maggi, Butera & Mugny, 1996; Pérez, Dasi & Mugny, 1996).

A second result that deserves mention concerns drawings performed in different directions. For all three lengths, the top-down drawing (↓) is shorter than any of the other drawings (see contrasts in Table 1). Yet more striking is that this line differs significantly ($p < .02$) from the line drawn bottom-up (↑). This comparison is important as it indicates that, despite the fact that these two lines present the same perspective for the subjects (sagital plane, perpendicularly with respect to their eyes), the relevant factor is that the lines are produced in opposite directions. One can see that direction is the more important determinant of the differences than vertical-horizontal orientation; only for the 8 cm line does the bottom-up drawing (↑) differ from the horizontal one, but this difference was not found either for the 4 cm or the 12 cm line.

Discussion

The predicted difference between the mm and the cm was not found. On reflection, one reason for this could be the difficulties subjects had in applying the mm to this type of object for which the cm provides a better fit. Even if we had asked subjects to use metres or kilometres, they probably would still have used centimetres, because it is the prototypical unit for lines of this length. This leads us to suppose that object categorization preceeds length estimation (cf. Stuart, Bossomaier & Johnson, 1993). It seems likely that this categorization involves a global evaluation of the object length by comparing among reference units (inch vs span; foot vs rod; step vs mile vs league in the anthropocentric system; mm vs cm vs meter vs km in the decimal metric system)[4]. Subjects may find it hard to state precisely how many centimeters a line of 8 cm has but easy to say that it is not a mm, or a metre or a kilometre. Once the reference category for measuring the object has been selected, that category will serve to analyze the object length, applying the prototype unit of that category.

Other results are no less interesting, despite the absence of differences between mm and cm conditions. In the first place, an inverse correlation was found between estimates and drawings which suggests that the mental cm is underestimated and accordingly causes an overestimation of the object analyzed with this unit. In the second place it was found that the mental cm applied vertically is even more underestimated than when applied horizontally. This effect, however, seems to reflect corrections in meaning provided by perspective rather than two concepts of the cm which differ according to direction. Given that the top-down drawing is longer than the bottom-up, one might suppose that there are at least two centimeters for the vertical, but this conclusion is rather speculative.

4 Probably talking of length in terms of short, medium and long indicates that for most purposes only three length categories are considered, namely the categories corresponding to cm, metre and kilometre respectively. It is more common to hear about centimetres than about millimetres. It is very unusual to deal with objects that require the use of millimetres.

It seems more parsimonious to suggest that the line length judgments are influenced by figural inferences, so that spatial orientation (vertical vs. horizontal) or spatial direction (top-down; bottom-up) allow the same straight line to symbolize some anthropomorphic category (e.g. withdrawal, descent, height, distance). These categories could activate compensatory systems of the retinal images depending on the previous experience of the observer (cf. Gregory, 1963). Thus it is likely that the top-down vertical line symbolizes *height,* while the bottom-up vertical line symbolizes *distance.* The perception of an image symbolizing height will be more distorted than one symbolizing distance, probably because the subject has less experience in correcting images from high points than images at distance. One could speculate that subjects feel more pressure to compensate an image of height than one of distance, perhaps because the former is seldom practiced. After all when we see a person or a car 300 metres away we correct the retinal image without any phenomenal experience of making this adjustment. If we look down from the top of the Eiffel Tower, we still have the phenomenal experience that the persons and cars moving down there are very small. Nonetheless, this does not explain why the distortion is in the direction of an overestimation of the line symbolizing height compared to a line symbolizing distance.

There are other possibilities. On the one hand, subjects may have an inappropriate concept of a centimetre measure; their mental centimetre may be smaller than the objective centimetre. If this is the case, it would explain the phenomenon of length overestimation in general terms but not the differences in overestimation that we observed as a function of directions and orientations. Proposing the existence of two or three concepts for the cm does not seem very parsimonious either. A possibility we attempt to test on the next study is that the overestimation effect could arise from the uncertainty the subject experiences with the task. Subject uncertainty about the task could also explain why the bias does not occur to a significant degree with the 4 cm line: the more cm units that are required to analyze a particular line, the more difficult will be the task of estimating at a rough guess the length of the line. After all, the task implicitly involves an accuracy norm (try to be as accurate as possible) and, fearful of making a mistake, the subject would maximize the value of the object, since the task demand is to estimate line length with the greatest mental accuracy possible, which is to say, by according importance to small parts of the line in using the measurement units of the metrical system (a cm; a mm), in contrast to the relevant unit in the more natural anthropomorphic system.

Finally, only the drawings were varied as a function of direction in this study. Estimates of lines with different orientations were not involved; only estimates of the horizontal line were requested. Consequently, it remains possible that the bottom-up drawings differ from the top-down ones because of sensorimotor differences. The following study was devised to examine these questions.

Study 2

Procedure and design

This study was conducted with a sample of 32 subjects (16 men and 16 women) drawn from different professional settings (none were university students), aged between 19 and 61 years (mean = 34.97; Sd = 11.02)[5]. Subjects were tested one at a time by the same experimenter. The procedure was basically the same as that in the previous study. The objective, however, was to examine the effect of direction not just for drawing, as in the previous study, but also for the estimation of lines. Subjects were first required to estimate the length of 8 cm lines (the only size used in this study in order to decrease task redundancy) presented in different directions and orientations. Dina-4 size sheets were used. Estimates of two kinds were employed, namely with and without direction. In the "without direction" condition subjects were asked to estimate the length of both horizontal (–) and a vertical (|) lines in cms, the lines being presented in a counterbalanced order. Subjects made these estimates before estimating lines with directions. For the estimates with direction the procedure began with the subject being told: «The line I am showing you has been drawn in a direction that goes from A toward B (the alternatives were ← vs ↑ vs → vs ↓; order of presentation was counterbalanced). Overdraw it in the same direction *trying* not to deviate from the presented line. Now tell me how many centimetres you think it measures».

On completing the estimation task subjects were presented with a 15 cm line. They were then asked to divide it into segments of 1 cm each. Then subjects were asked to draw 8 cm lines in different directions (← vs ↑ vs → vs ↓; order counterbalanced). Once this task was finished, and to test the hypothesis that increased subject uncertainty will increase the cm underestimation, subjects were asked to draw, with closed eyes, 8 cm lines in the four directions (← vs ↑ vs → vs ↓; counterbalanced order).

The prediction was that in the "blind" condition the cm used would be more substantially underestimated than in sighted condition, since the task uncertainty created by the former condition is greater. It was also predicted that with eyes closed subjects would not produce differences among directions, because no retinal image needs compensation. Furthermore, an absence of differences among directions in the blind condition would constitute good evidence against the explanation of differences in terms of sensorimotor differences involved in drawing in different directions.

Results

As has been mentioned here, there is a possibility that the so-called cm underestimation bias is nothing but subjects' ignorance of what a cm is. One could imagine that for some reason subjects think that a cm is smaller than it actually is. This was the reason for taking the opportunity in this study to test what subjects think a cm measures, using a procedure independent of the task of estimating the number of cms a line has. The method we used to do this was to ask the subject to divide a line into sections each

5 Age does not have any significant correlation with the length variables manipulated in the study (the highest correlation is p = .07).

of 1 cm. An average of 14.42 sections were obtained (Sd = 2.70) when dividing the 15 cm line into units of 1 cm each; 22.6% of the subjects divided the line in 15 parts exactly; 54.8% split it into less than 15 parts and the remaining 22.6% split the line into more than 15 parts. It can be concluded that subjects have a fairly precise knowledge of what a cm is. In any event, the average length for the applied cm (m = 1.05) tends towards overestimation rather than underestimation. In conclusion, the cm underestimations observed in study 1, and those found in the current study cannot be explained as mere lack of knowledge of what a cm is[6].

Let us now consider the results for estimates and drawings. An initial multivariate analysis of the drawn lines in sighted conditions and the estimates showed a main effect of estimations vs. drawings ($F/1,30 = 4.60$; $p < .04$) indicating that estimates are greater (m = 9.01) than drawings (m = 7.74), and also an interaction of the line position (horizontal vs vertical) with estimation vs drawing ($F/1,30 = 10.55$; $p < .003$). The interaction reflects the fact that vertical lines were estimated as longer (m = 9.20) than horizontal ones (m = 8.81; $p < .009$); it also reflects the fact that vertical drawings were shorter (m = 7.64) than vertical estimates (m = 9.20; $p < .05$), and also shorter than horizontal drawings (m = 7.85; $p < .07$). These results confirm that the cm as applied was globally underestimated and that vertical lines were more overestimated than horizontal ones. Both results tend to confirm those in study 1 with the 8 cm line.

Table 2 gives the means as a function of line direction. With regard to drawing length the corresponding effect observed in study 1 is also present here. Again we observe that the top-down vertical line (m = 7.38) is significantly shorter than the bottom-up line (m = 7.89; $p < .003$, see Table 2), and than either of the two lines drawn horizontally ($p < .009$). Note that the bottom-up vertical line does not differ from either of the horizontal lines. Even though in the previous study such a difference was obtained for the 8 cm line (the length used in the present study), in that study no corresponding difference was observed for the 4 cm and 12 cm lines. Thus the effect appear to be unstable, for reasons unknown.

With regard to the estimations, it can be seen (Table 2) that the vertical line without direction (m = 8.89) did not differ from the horizontal without direction (m = 8.86; $p > .50$). However, when a direction was given to the vertical line (top-down, m = 9.33; or bottom-up, m = 9.39), it was estimated as longer than either the equivalent line without direction (m = 8.89), the horizontal line without direction (m = 8.86; $p < .04$ and $p < .06$), or the horizontal line with direction (see Table 2 for *p* values). Note that no matter what the direction given to the vertical, when such a direction is given the estimate is longer than either the horizontal line or the vertical line without a prescribed direction. On the other hand, in none of the estimates was a significant difference found among different horizontal lines; these were unaffected by the presence or absence of a prescribed direction, the very the opposite of the case for vertical lines.

Means corresponding to lines drawn blind are also showed in Table 2. In all cases the drawings with eyes closed eyes are significantly shorter ($p < .001$) than the with eyes open. Furthermore, there are no differences among different orientations ($p > .34$). Correlations turned out to be negative with estimates but positive with drawings with eyes open. This suggests that the dynamics are the same whether the drawing is done with opened or closed eyes; the only difference is that the line drawn is underestimated more substantially with eyes closed. Taking these results into account, it seems difficult to explain the differences between vertical and horizontal lines in terms of different sensorimotor requirements of each, given that there were no differences between the alternative orientations in the blind condition.

6 In another study (N = 438) we carried out a test of recognition of 1 cm. Subjects were confronted with 11 counterbalanced alternatives ranging from 5 mm to 15 mm (by steps of 1 mm). Subjects had to identify which of the alternatives seemed to correspond exactly to 1 cm. The results indicate that 22.1% of them guessed the alternative corresponding to 1 cm; 37.9% choose an alternative below 1 cm, and the remaining 40% choose an alternative above 1 cm. The resulting averaged cm is exactly 1 cm (Sd = 0.24 cm). This result also confirms that subjects identify what a cm is in an relatively unbiased manner.

Table 2: Estimates and drawings for different orientations of vertical and horizontal 8 cm lines. N = 32. Standard deviation in brackets

Orientation for lines	← a	↑ b	→ c	↓ d	Without direction – h	Without direction | v
Drawings	7.87 (2.15)	7.89 (1.94)	7.83 (2.08)	7.38 (2.18)	–	–
Contrast within drawings				a: .001 b: .003 c: .009		
Estimations	8.83 (2.91)	9.39 (2.74)	8.73 (2.40)	9.33 (2.41)	8.86 (2.72)	8.89 (2.86)
Contrast within estimations		a. .06 c: .02 v: .05 h: .06		a: .04 c: .02 v: .05 h: .04		
Drawings vs estimations p <	.21	.06	.26	.02	–	–
Correlations:						
estimations & seeing drawings (all p < .01)	−.75	−.63	−.67	−.69	–	
estimations & blind drawings (all p < .03)	−.62	−.58	−.39	−.59		
seeing drawings & blind drawings (all p < .01)	+.53	+.55	+.56	+.62		
Blind drawings	5.87 (1.93)	5.78 (1.44)	5.69 (1.54)	5.87 (1.58)		

Discussion

There are several results in this study that deserve comment. In the first place, subjects seemed to know what a centimetre is and identified it in a relatively unbiased manner. If these subjects were able to apply their knowledge of what a cm is when measuring length, then one should not find significant differences between drawings and estimations. These differences confirm once again that the cm the subject uses when measuring is shortened in relation to the objective cm and, more important, also in relation to their own knowledge of what a cm is. This all seems to indicate that when estimating the length of a line some factor is involved in addition to subjects' geometric notion of the centimetre. According to our hypothesis this factor could be normative constraint, which should be greater when one has to estimate the length of a line than when one has to give an estimate of what a centimetre is. The possibility of error is greater in the first case than in the second. But before commenting in more detail on this possibility we will summarize the remaining results in this study.

A second important result is that vertical lines with direction (that is to say, anthropomorphized) are overestimated in relation to the horizontal lines or to the vertical line without direction. Lines drawn blind involved greater underestimation than sighted line drawings, and moreover there were no differences among the lines drawn blind in different directions. According to our hypothesis this set of results may be explained in terms of the uncertainty the task involves for the subject. The more uncertain the task is, the greater the object overestimation or the complementary underestimation of the applied cm. Supposing that confidence in estimations is a function of the practice one has in the estimation of a given length, the different tasks may be ordered from less to greater uncertainty in the following way: least uncetainty will be involved in estimating a centimetre, followed by estimation of the length of a horizontal line, with estimation of the length of a vertical line involving more uncertainty (in a context defined by a Dina-4 sheet; subjects would have less practice in vertical length estimates than in horizontal ones, due to writing habits, cf. Codol, 1985); the maximum degree of uncertainty, finally, would occur in the blind task. This assumes not that the vertical cm is more substantially underestimated than the horizontal, but that the vertical task involves greater uncertainty, due to a lack of practice. The effect of line direction could be explained in the first place by supposing that vertical lines with direction symbolize withdrawal with the vertical top-down lines symbolizing height, and vertical bottom-up lines symbolizing distance to the horizon. Secondly, we assume that estimations are made more often in the sagital plane (perpendicular to the eyes) than in the vertical plane (height). Taken together these considerations suggest that height estimations are harder to make than those of distance, because individuals have less practice in estimating height (e.g. buildings) than horizontal distances (e.g. streets).

As to why increased uncertainty would induce overestimation and not underestimation of the appraised object, our hypothesis is that uncertainty occurs because the task is saturated with the social norm of accuracy (or precision). In determining the length of the lines, subjects assumed that they were expected to be as accurate and exact as possible. The greater the emphasis in the task on being careful and the more concerned subjects are with not transgressing the norms, the greater the underestimation of the applied cm. It is assumed that subjects prefer to shorten rather than to lengthen the line.

Although the results of this study seem to confirm our hypothesis, a third study was undertaken in which we directly manipulated the extent to which not transgressing the accuracy norm is emphasised by the situation. For this purpose, we drew upon the proposition that the regulative quality of a norm is more enhanced when that norm proscribes than when it prescribes (Heilman & Garner, 1975).

A further objective of this third study was to examine why the different orientations of lines in the blind condition did not produce any differential effect. Some studies carried out with genuinely blind people have shown that they do overestimate vertical compared to horizontal lines (Heller & Joyner, 1993). In our case, we expected that this overestimation effect could also be produced when drawing blind if we led the subjects to imagine that the vertical line represented either an image of distance or an image of height. It is possible that in the previous study the drawings made blind were not taken to represent such things because subjects were given the instruction to start from a marked point and in a given direction, and were drawing the eight cm line on a plain surface. That is to say, once the eyes are closed all the visual cues that activate a possible interpretation in terms of perspective disappear (i.e., those cues that supposedly intervene when seeing the vertical line that is already drawn or that is being drawn). However, if such a symbolism is projected onto the line, it does not follow that this symbolism can only be activated through visual cues. For the effect to occur it should suffice to ask subjects to draw a line representing either height or distance.

Study 3

Procedure and design

In a mixed design, participants (36 undergraduate students) were required, with eyes closed, to "try to draw an 8 cm line, as accurately as possible" (prescriptive condition). Once they had drawn the first line, they could open their eyes and see what they had drawn. Subjects were then asked to close their eyes again and to "try to draw not an 8 cm line, but one as close as possible to 8 cm, either just over or just under" (proscriptive condition). This manipulation of prescriptive vs proscriptive versions of the accuracy norm was therefore a within-subject factor. Implicit in this manipulation was that in the proscriptive condition the principle of not transgressing the accuracy norm will be stronger than in the prescriptive condition. The rationale was that in the proscriptive condition subjects have to attend more to expectancies: draw a line that is close to 8 cm (as in prescriptive condition), but also try to avoid 8 cm exactly. If the cm underestimation is influenced by psychological process arising from constraints implied by social norms regulating the task, then we would predict an amplification of the cm-underestimation bias when the norm is expressed in proscriptive form.

The order in which the norms were invoked (prescriptive/proscriptive vs proscriptive/prescriptive) was manipulated as a between-subjects factor. One experimental group (n = 19) drew lines first according to the prescriptive form of the norm and then the proscriptive form (a line that was 8 cm, then a line that was not 8 cm), while the other group (n = 17) drew lines in the reverse order.

Once the two horizontal lines had been drawn, and continuing with the same order (8 cm / not-8 cm vs not-8 cm / 8 cm), subjects were asked to draw blind these two lines in a vertical top-down direction. Finally, retaining the same experimental order for the norms, subjects were required to draw, still blind, vertical bottom-up lines. Instructions for both these directions were given orally by the experimenter, symbolizing them with arm movements, that is, with three-dimensional cues.

Results

A multivariate analysis was carried out with the following factors: direction of line drawn (horizontal vs vertical bottom-up vs vertical top-down), form of the norm (prescriptive-8 cm vs proscriptive-not-8 cm), and drawing order (prescription/proscription vs proscription/prescription), with repeated measures on the two first factors.

The results (see Table 3) indicate a marginally significant effect for the order in which lines were drawn ($p < .07$). The univariate analysis indicate a significant difference only for the horizontal line ($p < .02$); the horizontal line that was drawn first was longer than the line that was drawn next; that is to say, subjects had the impression that the first line was too long, even though it was shorter than 8 cm. The factor not-8 cm vs. exactly 8 cm produced an overall effect for the three lines ($p < .03$); the univariate analysis confirmed significant effects for the horizontal line ($p < .04$) and for the bottom-up vertical line ($p < .004$). The difference for the top-down vertical line with no direction was of the same kind but did not reach significance ($p < .15$). Thus, overall subjects produced drawings which involved greater underestimation when given the instruction "not-8 cm". Recall that the instruction given also offered the possibility of producing a line longer than 8 cm. Finally, highly significant differences among the type of lines were found ($F/2,67 = 15.9$; $p < .001$): the horizontal lines were longer ($m = 6.88$) than the vertical top-down lines ($m = 5.95$; $p < .001$) and also longer than the vertical bottom-up lines ($m = 6.22$; $p < .001$). There was tendency only verging on statistical significance among vertical lines ($p < .071$): the top-down vertical line ($m = 5.97$) tended to be shorter than the bottom-up vertical line ($m = 6.22$). Comparing the lines with different directions as a function of whether they were drawn under the "exactly 8 cm" vs the "not-8 cm" instruction, one can see that the horizontal line was always longer than any of the vertical lines ($p < .02$). Turning to the vertical lines, and depending on whether the subjects were asked to draw the 8 cm line or the not-8 cm line, there was a significant effect when the instruction was "exactly 8 cm" (bottom-up mean = 6.70; top-down, mean = 6.23; $p < .02$), and not when it was "not-8 cm" ($p > .11$).

Discussion

First, given that subjects saw what they had drawn it is curious that there was not a more marked corrective effect of this feedback. Observation of the first horizontal line did produce

Table 3: Blindly drawings of a line of exactly-8 cm vs no-8 cm (N = 36). Standard deviation in brackets

	Order for drawing		
	Drawn first	Drawn after	Total
Horizontal (left to right →) exactly 8 cm	7.73 (1.72)	6.91 (2.00)	7.34 (1.88)
Horizontal (left to right →) not 8 cm	7.06 (1.70)	5.87 (1.03)	6.43 (1.49)
Vertical top-bottom (↓) exactly 8 cm	6.33 (1.54)	6.05 (1.48)	6.20 (1.49)
Vertical top-bottom (↓) not 8 cm	5.86 (1.42)	5.56 (1.42)	5.71 (1.41)
Vertical bottom-up (↑) exactly 8 cm	7.08 (1.67)	6.28 (1.07)	6.70 (1.46)
Vertical bottom-up (↑) not 8 cm	5.82 (1.23)	5.65 (1.26)	5.73 (1.23)

an effect on the line drawn next, but the effect took the form of exaggerating the underestimation bias, not correcting it. This bias is therefore probably highly resistant to practice given the uncertainty involved in performing the task blindly.

Second, the proscriptive form of the norm (not-8 cm), compared to the prescriptive form, increased the bias, as predicted. Third, we found that the orientation of the lines drawn blind reproduced the bias found when the lines were drawn in the sighted condition in previous study. This therefore confirms our hypothesis that verbally activating what the drawing symbolizes is sufficient to produce the effect in the absence of visual cues. An interesting result is that the effect of the proscriptive form of the norm was weaker for vertical lines drawn in a downward direction. This is possibly due to a ceiling effect: this line has already been considerably underestimated; it may perhaps already be at a maximum for this bias.

General discussion

Both length estimation and length drawing tasks involve a number of factors at distinct levels and the relation between these different factors needs to be considered (cf. Doise, 1986) if we are to achieve a more comprehensive account of a task that at a first glance may appear simple but that finally turns out not to be simple at all. Initially, the only relevant factor involved in the task of estimating the length of short lines (4 to 12 cm) appears to be the concept of a centimetre. At this level, the task demands only that the subject acts as a mere geometrician. However, we have seen that, even though subjects have relatively unbiased knowledge of the length of a single centimetre, when faced with the task of estimating the length of a line in centimetres or when drawing lines of a specified length, the lengths of their lines were biased toward overestimation as a result of applying an underestimated cm. Furthermore, the fact that this bias is more or less accentuated as a function of the orientation and direction of lines (vertical are more overestimated than horizontal, and vertical top-down more overestimated than vertical bottom-up), led us to conclude that other factors are involved.

It seems necessary to add that subjects are not simply geometricians, applying cognitive adjustments to the images projected on their retinas as a function of their previous knowledge of the object of perception. These complex cognitive processes have been extensively conceptualized (see Gregory, 1974) and these approaches describe, in various ways, the cognitive operations which intervene to adjust what something appears to be to what it is. These adjustments are generally correct, but bias can occur in some situations. Cognitive approaches of this kind explain biases by assuming that the subject is misled by the object, because it inappropriately activates the central cognitive system which then makes an unnecessarily compensation (cf. Gregory, 1974).

Taking instead a more social psychological view of the task, the theoretical line we have pursued in our research begins with the following general hypothesis: It is necessary to take into account social psychological factors that serve as organizing metaprinciples for cognitive activities (Doise, 1993). At this third level of analysis, the accuracy norm and also the sense of uncertainty the task generally creates for the subject represent social psychological factors that are relevant to the task. Furthermore, the feeling of uncertainty (i.e., the psychological effect created by the accuracy norm) will be more or less reinforced as a function of any contextual conditions that make salient an accuracy norm stressing the expectation another might have of the subject in such situation.

In conclusion, to understand the nature of the specific effect (i.e. overestimation vs underestimation) to which both uncertainty and normative pressure give rise, its seems approriate to take into account the existence of two representations of length, namely the anthropocentric and the geocentric. Each has a meaning that stems from their mutual comparison. The geocentric representation symbolizes accuracy and precision, compared to the more coarse anthropocentric representation. Thus, the metric system within which the task is presented to the subject inevitably invokes a geocentric representation and the accuracy norm that characterized it, in contrast to the anthropocentric system, which is more natural to the non-expert but also less fine or precise.

The direction in which accentuation of the bias occurs (i.e. object size overestimation rather than underestimation) will depend on the fact that estimating and drawing lengths using the metric system of the centimetre presumes an object representation (representating the value of length of an object) that is different to the object representation presupposed within an anthropocentric system. Coexistence of both representations necessarily creates a tension (i.e. when using the decimal metric system one has to be more careful than when using the anthropomorphic system, which is less precise for shorter lengths) that may give rise to some uncertainty and this would would result in the overestimation bias because the metric decimal system has, compared to the anthropomorphic, the property of according more value to the object because smaller fragments of it may be taken into account.

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