Do Children Have Similar Models of Understanding for Seeing, Hearing, and Smelling?

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Abstract

The drawings and annotations of 7- to 11-year-old English children suggest that, overall, they seem to use five models for the senses of hearing, smelling, and seeing: the receptor, outreaching, sensing-as-instant, clashing-arrows, and arrows-both-ways models. There is some evidence that children's models are context-driven, in that they often have totally different models for each of their senses.

Introduction

Many curricula include information about seeing, hearing, and smelling, and an appreciation of these senses is related to an understanding of the behaviour of light, sound, and gases. The National Curriculum for England (Department for Education and Employment, 1999) requires hearing to be taught in Year 5 and seeing to be taught in Year 6, stating that pupils should be taught that "vibrations from sound sources require a medium through which to travel to the ear" (p. 88) and "we see things only when light from them enters the eye" (p. 88), respectively. There is no specific requirement to teach about the sense of smell.

What kinds of models do children bring to their learning, and how can this knowledge inform teaching strategies? Do children have similar models of understanding for seeing, hearing, and smelling? Many children do not see light as something that travels from a source. Rather, as La Rosa, Mayer, Patrizi, and Vincentini-Missoni (1984) indicated, daylight is seen as providing a flood of light that enables sight. Watt and Russell (1990) said that children often make a connection between sound and the loudness, or proximity, of the source. Russell, Longden, and McGuigan (1991) suggested that most children realise that smells come from a source, but smelling was seen as a passive activity if odours were invasive and unavoidable. The studies reported that children thought their sense organs were the reason they sensed, and this suggests that some understand seeing, hearing, and smelling as occurring instantaneously, and that there is no necessity for light, sound, or gases to travel.

Some research indicates that a number of children understand vision as an outreaching of the sense, and that they are the originator of the process (Eaton, Anderson, & Smith, 1983; Guesne, 1985). The children draw arrows or rays that point out of the eyes, sometimes returning to the head, and write that vision involves the eyes seeing or looking and that they see things when they turn their head and face towards an object. The use of the terms "see through" (when referring to transparent materials), "to look daggers" (Guesne, 1985, p. 26), and "cast your eyes over this" (Anderson & Karqvist, 1981, p. 401) reinforce an outreaching model of vision.

There is less evidence for the outreaching of the nose in smelling, although there is perhaps some indication of such in Russell et al. (1991) when they say that one fourth of the children, of all ages, explained smelling as something that the nose did. It is evident that children see smelling as an active process in which smells are sought by sniffing. Watt and Russell (1990) did not explicitly say there is outreaching of hearing, although there is evidence of children believing the ear actively

listens, as their drawings of hearing and smelling sometimes included an outreaching model shown by an arrow pointing from the sense organ towards the source.

Crookes and Goldby (1984) and Harlen (2000) found that some children thought light first entered the eye and then went to the object. This could be an attempt to reconcile the information that adults are giving them, about light entering the eye, with their original understanding that vision is an outreaching of the eye.

Watt and Russell (1990), Osborne, Black, Smith, and Meadows (1990), and Russell et al. (1991) suggested that the models of seeing, hearing, and smelling are context-driven. Taber (2003) and Pope and Denicolo (1986) also proposed that children may have several alternative models for the same concept, all of which are used regularly in different contexts. When later learning begins to decay, children may fall back on primitive concepts of seeing, hearing, and smelling, concepts that Ausubel, Novak, and Hanesian (1976) said are amazingly tenacious and resistant to extinction. Further research suggested a consistency in these naive models across different ages, cultures, and sexes (Champagne, Gunstone, & Klopfer, 1983).

According to Osborne et al. (1990), “not only are the children developing, but also clearly there are some children whose explanations and ideas are regressing. This would support a model of development of children’s ideas that is non-linear and may consist of five steps forwards and one step back” (p. 62). Is there a development through various models, or is there purely a random walk of learning? The fact that children’s scientific understanding may be chaotic, fluid, and context-driven enables conflicting concepts to be retained, and this would suggest that children would likely have different models for each of their senses.

Methodology

An increasingly substantial amount of research has used children’s drawings to explore their understanding of concepts, from the hydrological (Dove, Everett, & Preece, 1999) through knowledge of the shape of the Earth (Arnold, Sarge, & Worrall, 1998) and understanding of forests and their inhabitants (Strommen, 1995). As Hayes, Symington, and Martin (1994) reported, it is a technique that enables an exploration of ideas that draws on holistic understandings and prevents children from feeling constrained by trying to match their knowledge to that of the teacher. Rennie and Jarvis (1995) suggested that there are some ideas that can be more easily expressed through drawings than written description. This study uses an analysis of children’s drawings and annotations to glean their ideas about the senses.

According to Hayes et al. (1994), for many children drawing is a favourite method of communication in science, and this method of gaining insight into children’s thinking also avoids the pitfalls associated with interviewing--even with experienced researchers. Children have a powerful perception of adult non-verbal communication, exemplified by the intense scrutiny experienced by any student teacher who has entered a classroom apprehensively. We have to acknowledge the importance of body language when interviewing children, particularly when they are “clutching at straws” of meaning in order to understand the world. In addition, although an everyday skill for a practicing teacher, Kuiper (1994) believes that classifying children’s responses in interviews is difficult and, as Taber (2003) suggested, time needs to be taken to build up an idea of how children use language. The complexity of children’s thoughts may not always be identified and, as Watts and Gilbert (1983) said, children often use technical terms in everyday or idiosyncratic ways, and understanding their comments is not an easy exercise.

In this study, drawings were used to sample the ideas of Year 3-6 boys and girls (7- to 11-year-olds), from one school in a fairly prosperous area of an English West Midland industrial town, during the autumn term of 2003; and all in the same week. Of the 335 children, 85 were in Year 3, 84 in Year 4, 88 in Year 5, and 78 in Year 6. The children came from a number of different cultural groups that included Indian, European, West Indian, and Pakistani. In English schools, children change year groups each year regardless of their achievement, and there is little mobility between schools. While the students in this school are taught hearing and smelling in Year 5 and seeing in Year 6, this research was conducted at the beginning of the academic year before such teaching had occurred that year.

Each child was given three sheets depicting a clip-art scenario for each of seeing, hearing, and smelling (see Figures 1-3, respectively), together with pencils and erasers. They were asked to "use lines, arrows, and words to show how your see, hear, and smell," and worked on their own without any further intervention. Following an initial examination of results, a relatively small number of 30 children were interviewed in an attempt to confirm the analysis of the drawings. A sample of children from each of the models described in the following was interviewed.

Models: Findings and Discussion

The understanding of seeing, hearing, and smelling of the vast majority of Years 3-6 children can be represented by three main models; the receptor, outreaching, and sensing-as-instant models. While these models are common to all senses, we will see later that individual children do not necessarily use the same model for each sense. Another two models--the clashing-arrows and arrows-both-ways models--are seen in a relatively small number of children. In addition, there are two models unique to seeing: the sun-eyes-object and bounces-off-sun models.

Model 1. *A more or less acceptable scientific view involving a* ***receptor model****, where light, sound, and smells travel to the relevant sense, as indicated by arrows and/or annotations.*

Much of the vocabulary used by the children is similar, and involves annotation of the lines and arrows with comments such as "light goes to your eyes," "light travels or comes to my eye," the Sun will reflect its light so we can see," "light reflects into our eyes," and "light bounces off and into our eyes," as exemplified in Figure 1.

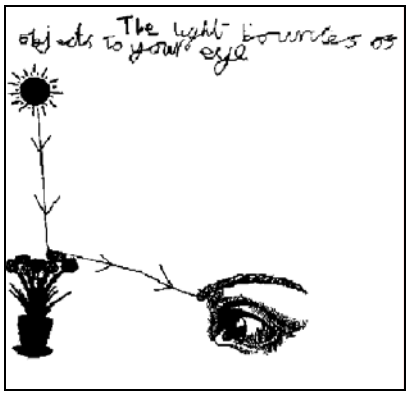

Figure 1. Seeing: Receptor model of an 11-year-old boy. "The light bounces of [*sic*] objects to your eye."

Hearing involves sound travelling, sometimes by sound waves or vibrations, through the air. One child said "sound travels in wavy lines so it takes longer for you to hear things than it takes light to reach things." Sometimes sounds flow, or just go to the ear (Figure 2).

Smells “travel” (Figure 3), “go,” “rise,” and “come to the nose.” The words “wafts,” “drifts,” and “flows” were also used to indicate smells travelling. The children wrote annotations like “I think that you smell the vinegar by the smell drifting up to your nose,” and during interview one said: “You can smell vinegar because the smell goes up your nose so the smell is just air--just air in the opposite direction.” Although this is a good representation of the responses and words used, they were used in different combinations. As with the other models, many children did not write anything, using arrows alone to explain what they meant.

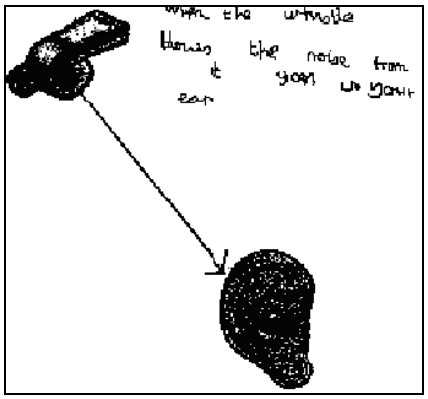

Figure 2. Hearing: Receptor model of a 9-year-old boy. “When the whistle blows the noise from it goes in your ear.”

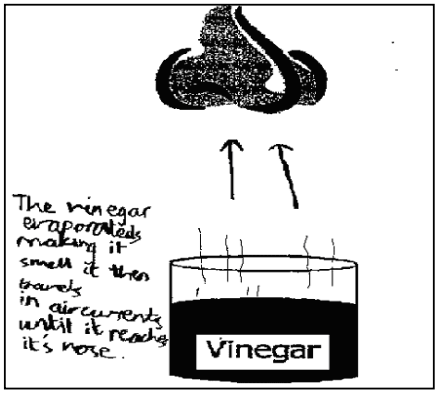

Figure 3. Smelling: Receptor model of a 10-year-old girl. “The vinegar evaporates making it smell it then travels in air currents until it reaches the nose.”

Figure 4 shows the percentage of children, in each of Years 3-6, who display the receptor model (the accepted scientific model) for each of the three senses. The model is exhibited at all year levels. Generally, the Figure 4 percentages are less than about 50%, with hearing and smelling apparently better understood than seeing. However, this may not necessarily mean that understanding seeing is more difficult than understanding smelling and hearing, as the clip art used for investigating seeing (Figure 1) seeks acknowledgement of the reflection of light, whereas the clip art used for hearing and smelling (Figures 2 and 3, respectively) does not. The use of a light source, such as a candle or fire, as the clip art scenario for seeing would likely be more analogous with the scenarios of Figures 2 and 3, and thus provide for a more valid comparison of results.

It is tempting to draw more detailed conclusions, including trends for students as they age, from comparisons of the percentages shown in Figure 4. However, this appears inappropriate. Unlike in the case of a longitudinal study, for example, we do not know how well matched each of the year groups in this study are. Also, there is no statistical analysis to use as a basis for judging how meaningful especially a relatively small percentage difference may be.

Model 2. *An* ***outreaching model****, indicated by arrows pointing outwards from the sense organ and/or a corresponding annotation.*

The vocabulary used in the outreaching model was quite diverse. Children said that objects attract your eye or are eye-catching, or that the eyes concentrate on objects, go to the object, or even send a message. Light shines on an area and brightens it, enabling the seeing process to occur (Figure 5). A large number of these children said that the middle of the eye, the pupil or “the black bit in my eye,” helps a person to see, although this aspect was also seen annotating other models.

The hearing annotations involve the ears grabbing or pulling the sound, the ear listening or hearing, and the sound being attracted to the ear. The loudness of the noise was important (Figure 6). The outreaching annotations for smelling see children writing that “noses let you smell,” “nostrils smell,” “noses sense the smell,” and “noses pick up smells by smelling.” Other comments included: “You can smell the vinegar with your nose because vinegar has a strong smell,” “your nose is attracted to it,” “the nose goes towards the vinegar and that way it can smell the vinegar,” and “the nose is smelling the vinegar” (Figure 7).

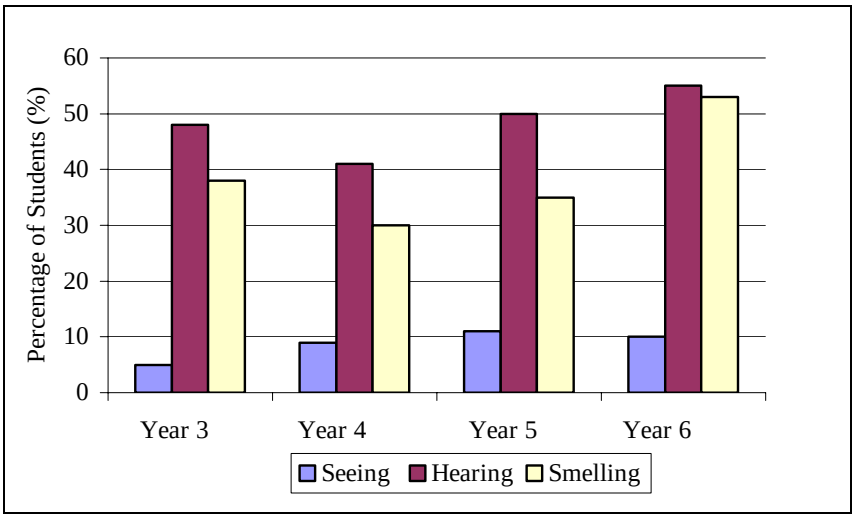

Figure 4. Percentages of children displaying the accepted receptor model for sensing.

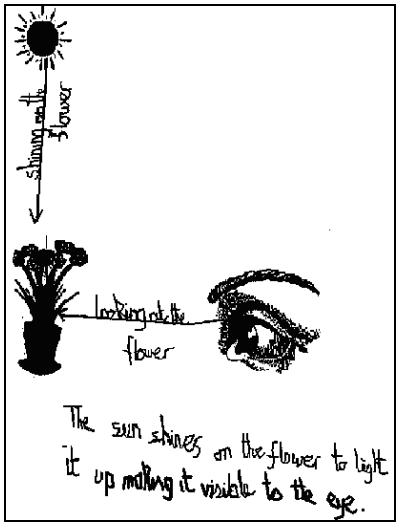

Figure 5. Seeing: Outreaching model of a 9-year-old girl. “The sun shines on the flower to light it up making it visible to the eye.”

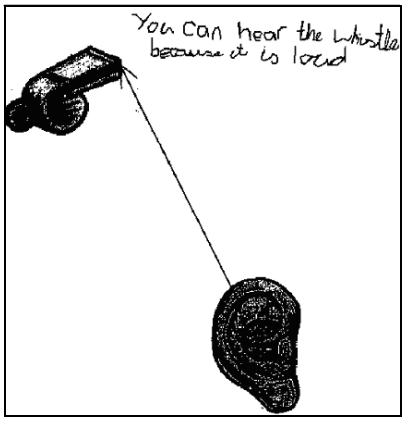

Figure 6. Hearing: Outreaching model of an 8-year-old girl. “You can hear the whistle because it is loud.”

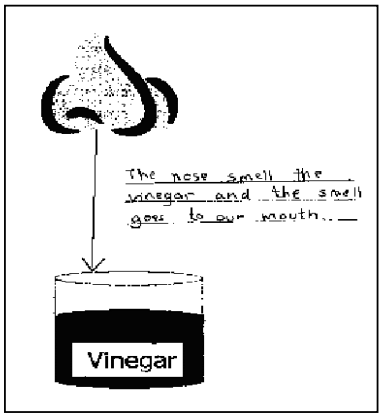

Figure 7. Smelling: Outreaching model of an 8-year-old girl. “The nose smell [*sic*] the vinegar and the smell goes to our mouth.”

The outreaching of the eye is perhaps more common than outreaching of either of the other two senses (Figure 8). The prevalence of the outreaching model across all year groups seems to suggest it is quite tenacious.

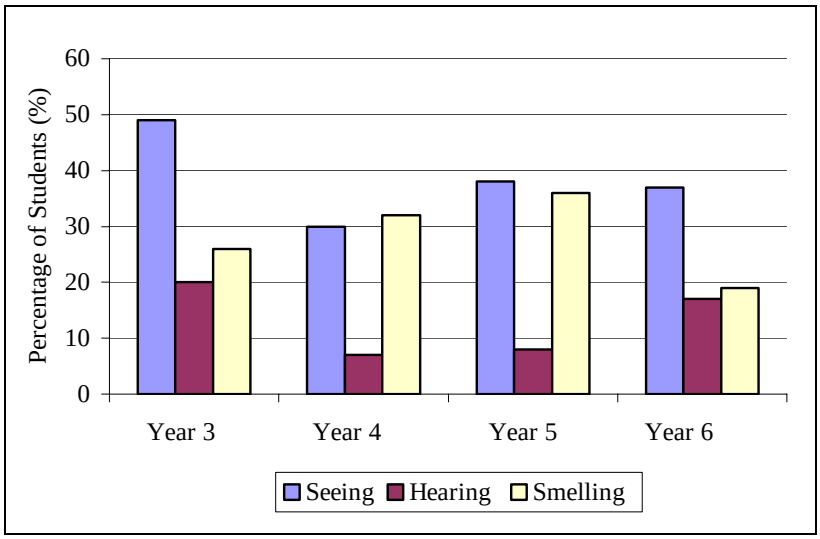

Figure 8. Percentages of children outreaching with their senses.

Model 3. *No indication of direction, either by arrows or annotation, possibly indicating that the children saw* ***sensing-as-instant****.*

These children resisted including arrows in their models, and did not seem to understand the necessity for anything that suggested travelling or movement, either as an outreaching of a sense or the receiving of a stimulus. There were usually, but not always, lines connecting the eyes, ears, and nose to the objects they were experiencing, but this seems to merely suggest that there is a connection between them. Eyes see, ears hear, and noses smell; so what is the problem? They clearly saw sensing of the environment as an instant response. These children were very reluctant

to use arrows or annotations to indicate the movement of light, sound, or gas, even when prompted quite overtly during post-drawing interviews.

The annotations for this model involved the eye seeing (Figure 9), the eye looking at, objects shining, and objects being made brighter by the sun. Further comments, not unique to this model, included that the sun makes it lighter, gives light, or shines so you can see better. Other children said, during interview, that they see when they turn their head, face towards an object, or when their eyes turn towards an object.

These children's concept of hearing involved the ear hearing (Figure 10), and that one hears because the sound is loud or piercing. They wrote such things as "I hear the sound instantly and very quickly," and said "the thing that is making the noise makes a vibration that is loud enough for you to hear." There may be an indication of a flooding of noise around them, as in "the whistle sound floods through the ear." When pressed during interview, they said "you just hear the whistle" and looked perplexed when asked to indicate the travel of sound by arrows.

Figure 9. Seeing: Sensing-as-instant model of an 8-year-old girl. "The Sun shines on the flowers and that way our eyes can see the flowers."

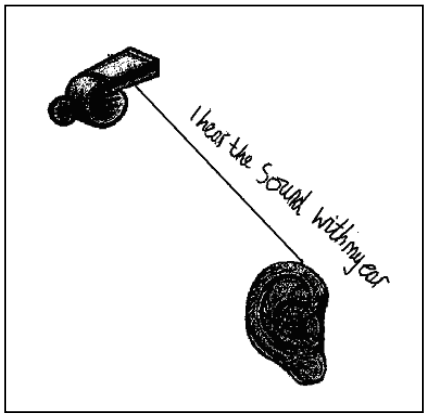

Figure 10. Hearing: Sensing-as-instant model of a 9-year-old boy. "I hear the sound with my ear."

Noses smell (Figure 11) or let you smell, and nostrils smell, pick up the smell, or "suck" it up. A number of the models with no indication of smells travelling did have annotations involving smelling as breathing in, inhaling, and sniffing. One child said, during interview, that "you can smell the vinegar because it has a strong smell when you smell it--it like clicks a trigger in your brain so you can tell what it is." Again, there was reluctance to show smells travelling from a source. As shown in Figure 12, there are a substantial number of children, in all year groups, who use a sensing-as-instant model.

Two further models. While most of the children in this study displayed the three foregoing models, another two, relatively uncommon (see Figures 16-18) models, possibly representing hybrid ideas, involve both an outreaching of the senses and an acknowledgement that senses react to stimuli. In the ***clashing-arrows model***, an arrow(s) from the stimulus towards the sense meets an arrow, pointing in the opposite direction, from the sense.

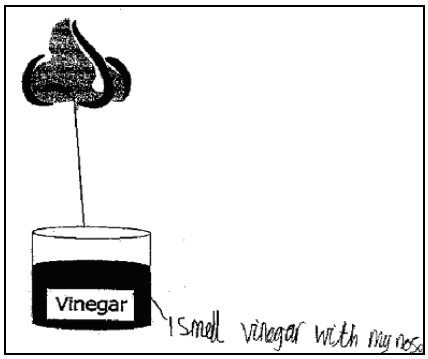

Figure 11. Smelling: Sensing-as-instant model of a 9-year-old boy. "I smell vinegar with my nose."

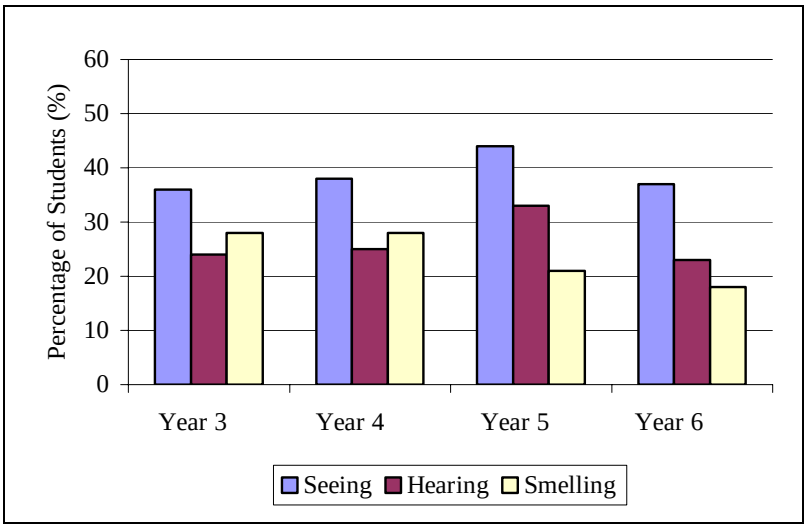

Figure 12. Percentage of children seeming to indicate that sensing is instant.

Then, there is the ***arrows-both-ways model***. For seeing, the model retains the outreaching model while also indicating an understanding that light enters the eye. Comments included "your eye can travel to the flower by having to see and when you see it travels from the eye to the brain." As Figure 13 shows, some annotations are similar to those in other models. Hearing annotations (e.g., Figure 14) were most varied, and included phrases such as "well your ear drum beats and comes out of your ear and they bounce together and brings [*sic*] the sound back into your ear. "For smell, children said that the smell goes all around the room and then the nose goes and gets it, or the nose smells and then it tells us (Figure 15).

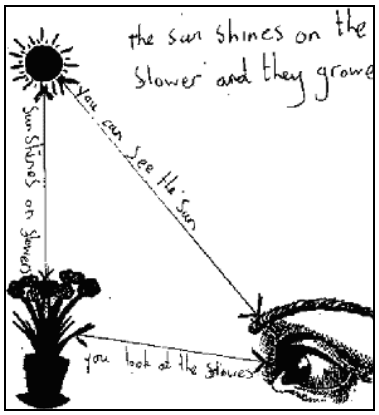

Figure 13. Seeing: Arrows-pointing-both-ways model of an 8-year-old boy. "You look at the flowers."

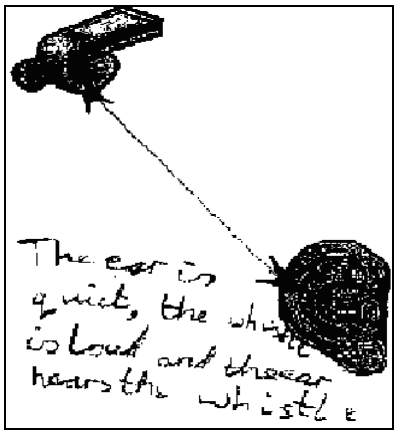

Figure 14. Hearing: Arrows-pointing-both-ways model of an 8-year-old girl. "The ear is quiet, the whistle is loud and the ear hears the whistle."

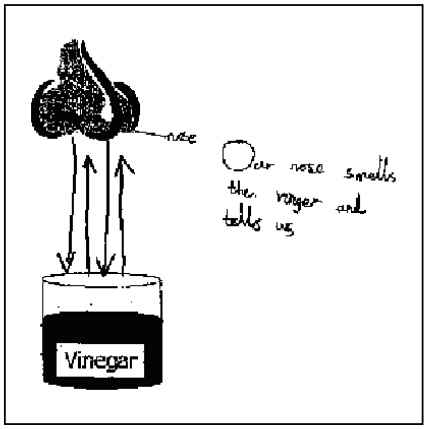

Figure 15. Smelling: Arrows-pointing-both-ways model of an 8-year-old boy. "Our nose smells the vinegar and tells us."

Same data presented by sense, and more. In Figures 16-18, the data of Figures 4, 8, and 12 are presented in a different way--by sense, rather than by model. However, as shown in Figure 16, two further models peculiar to sight are displayed. In the ***sun-eyes-object model***, where light from the sun hits the eyes and goes to the object, children wrote things like "the Sun shines into your eyes then you look at the flower so you can see," "the Sun reflects off your eye so you can see," and "the sun reflects in your eye and your brain can see the flower." Figure 19 shows another example. This model might be seen as merely an alternative way of explaining outreaching of the eyes, but it is found in a noticeable number of children in all year groups.

The ***bounces-off-sun model*** (Figure 20) is seen in relatively few drawings and annotations, and is further exemplified by the comment: "To see your eye needs some light your vision bounces off the sun to the plant." The hurt to the eyes associated with looking at the Sun would likely make this model unappealing to children.

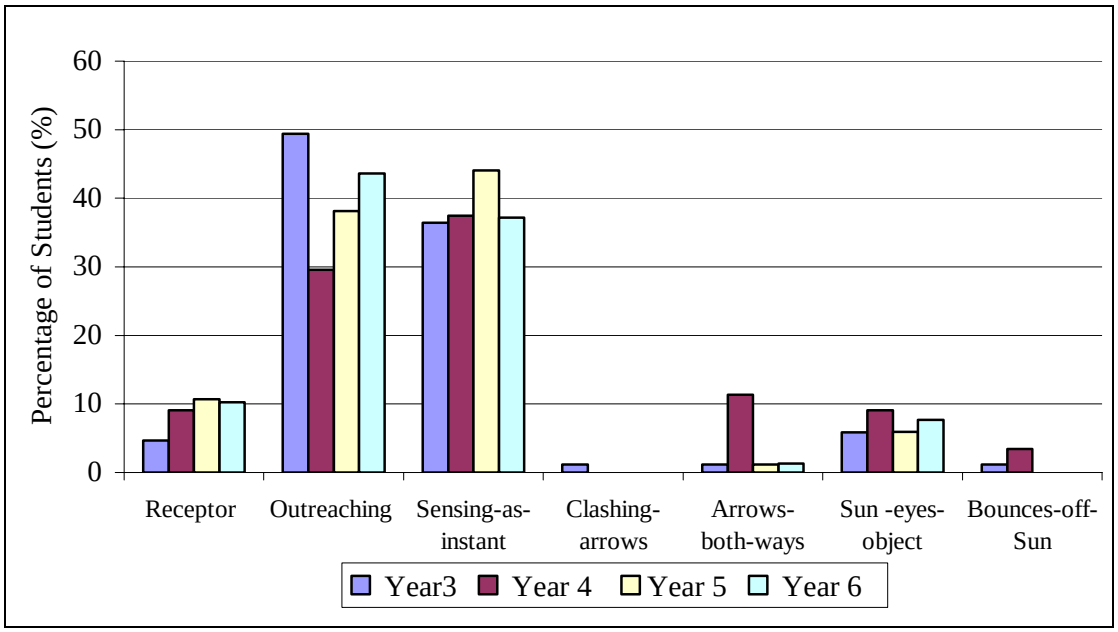

Figure 16. Children's models of seeing.

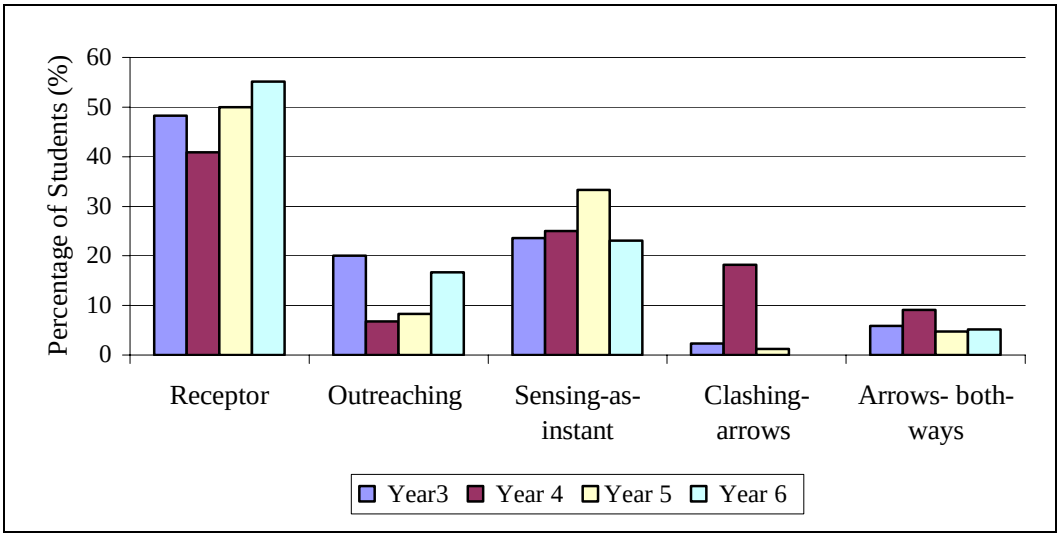

Figure 17. Children's models of hearing.

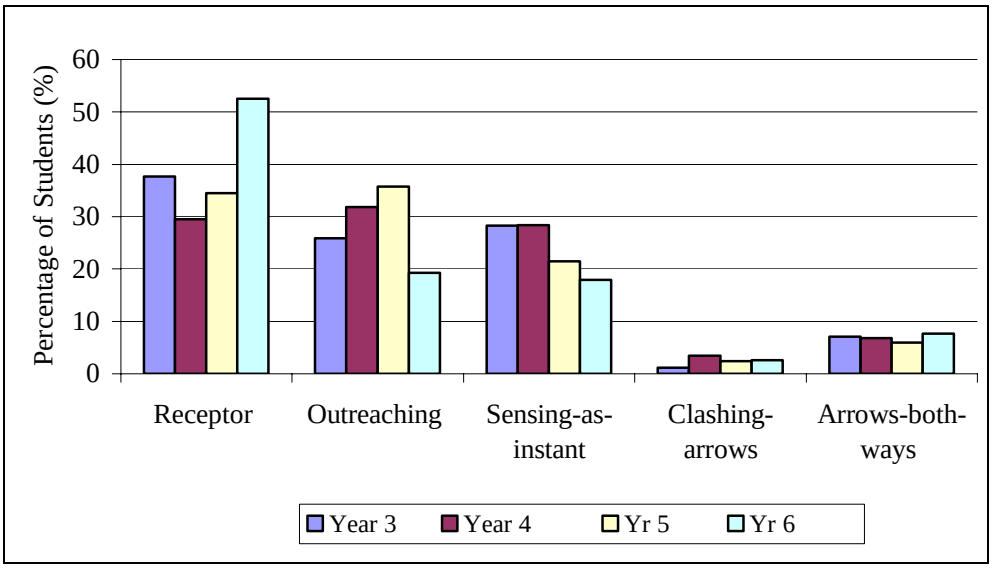

Figure 18. Children's models of smelling.

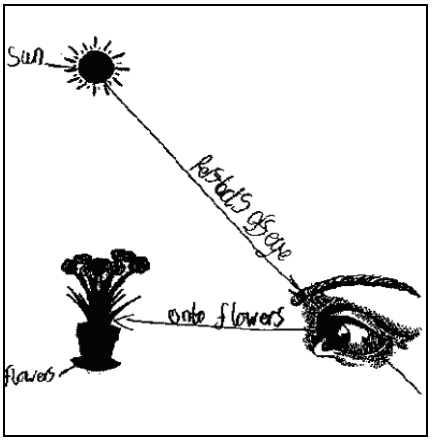

Figure 19. Seeing: Sun-eyes-object model of an 8-year-old boy. "Reflects off eye onto flowers."

Figure 20. Seeing: Bounces-off-sun model of an 8-year-old girl. "You look at the Sun and then the Sun will show on the flowers."

Do Children use the Same Model for Seeing, Hearing, and Smelling?

Having identified the different models children use, to what extent do they use the same models for different senses? In each year group, individuals who use similar models for all three, two only, or none of the senses have been identified, and Table 1 shows the results for Year 3. Thirty-one percent (1% + 4% + 26%) used the same model for all three senses, but most of these (26%) used a sensing-as-instant model. Only 1% of Year 3 children exhibited the accepted receptor model for all senses. While 53% did use the same model for two of the three senses, 15% used different models for each sense.

Table 1
Extent to Which Year 3 Children use the Same Models for Different Senses

Model	Percentage of children (%)			
	All three senses	Seeing and hearing only	Seeing and smelling only	Hearing and smelling only
Receptor	1	2	1	12
Outreaching	4	9	15	2
Sensing-as-instant	26	1	4	4
Clashing-arrows	0	0	0	0
Arrow-both-ways	0	1	0	2
Children with different models for each sense	15			

From Table 2, 41% (2% + 2% + 3% + 34%) of Year 4's used the same model for all three senses, and once again the vast majority (34%) of these used the sensing-as-instant model. Only 2% of Year 4 children exhibited the accepted receptor model for all senses. While 49% did use the same model for two senses, 9% used different models for each sense.

Table 2
Extent to Which Year 4 Children use the Same Models for Different Senses

Model	Percentage of children (%)			
	All three senses	Seeing and hearing only	Seeing and smelling only	Hearing and smelling only
Receptor	2	2	2	15
Outreaching	2	1	10	5
Sensing-as-instant	34	5	2	5
Clashing-arrows	0	0	0	0
Arrow-both-ways	3	0	0	2
Children with different models for each sense	9			

For Year 5's (Table 3), 52% (6% + 10% + 1% + 35%) used the same model for all three senses, with the sensing-as-instant model again predominating (35%). Six percent of children exhibited the accepted receptor model for all senses. While 36% did use the same model for two senses, 11% used different models for each sense.

Table 3
Extent to Which Year 5 Children use the Same Models for Different Senses

Model	Percentage of children (%)			
	All three senses	Seeing and hearing only	Seeing and smelling only	Hearing and smelling only
Receptor	6	1	1	14
Outreaching	10	0	8	1
Sensing-as-instant	35	2	0	8
Clashing-arrows	0	0	0	0
Arrow-both-ways	1	0	1	0
Children with different models for each sense	11			

Finally, for Year 6 children (Table 4), 39% (4% + 6% + 3% + 26%) used the same model for all three senses, with most of these (26%) yet again adopting a sensing-as-instant model. Only 4% of Year 6's used the accepted receptor model for all senses. While 53% did use the same model for two of the three senses, 9% used different models for each sense.

Table 4
Extent to Which Year 6 Children use the Same Models for Different Senses

Model	Percentage of children (%)			
	All three senses	Seeing and hearing only	Seeing and smelling only	Hearing and smelling only
Receptor	4	1	1	36
Outreaching	6	0	4	3
Sensing-as-instant	26	1	3	4
Clashing-arrows	3	0	0	0
Arrow-both-ways	0	0	0	0
Children with different models for each sense	9			

Table 5 summarises key data from Tables 1-4. Very few students (a range of 1-6% only, across all year levels) used the scientifically accepted receptor model for all three senses. Indeed, somewhat less than one half (range 31-52%) used the same model for all senses, and among these, the sensing-as-instant model predominated (range 26-35%), suggesting that it is a rather robust model. Around one half of students across the year groups (36-54%) used the same model for any two of the senses, with the relatively high 36% of Year 6 students using the receptor model for both hearing and smelling--probably evidence that the teaching they had received about these two

senses during the previous year had made some positive impact-- standing out in this set of figures. A quite substantial number of students (range 9-15%) in fact used a different model for each sense.

Table 5
Children who use the Accepted Receptor Model for all Senses, and Various Combinations of Models for the Senses

Year	Receptor model for all senses (%)	Same model for all senses (%)	Same model for two senses (%)	Different model for each sense (%)
3	1	31	54	15
4	2	41	49	9
5	6	52	36	8
6	4	39	53	9

In Conclusion

Overall, five common models were found, across all year levels, for seeing, hearing, and smelling. The receptor (scientifically accepted), outreaching, and sensing-as-instant models were the most prevalent, with the clashing-arrows and the outreaching/receptor model less common. In addition, the sun-eyes-object and bounces-off-sun models were observed in relation to seeing.

The outreaching and sensing-as-instant models appear tenacious, with neither apparently readily susceptible to the conventional teaching practices being adopted. I predicted that the children using the receptive model for one sense would likely use it for the other senses as well, but this is not borne out by the results, which show very few students using the receptor model for all three senses. To the contrary, a substantial proportion of students are in fact quite prepared to use different models for each of the senses.

The fact that children are unaware that, for example, sensing is not an instant activity, and that it involves stimuli travelling, may well reflect a limiting factor in their learning--the use of language. Children glean meaning both from what adults have told them and from their understanding of the language used. Could this mean that vocabulary is a constraining factor, restricting children's thought? For example, does describing materials as "see-through," rather than as "transparent," exacerbate problems? Does language describe models, or does language determine models?

It is really tempting, when dealing with data like that in this study, to look for trends across year groups, and the reasons for not doing so in this study were given earlier. It would be interesting to gather evidence, using a longitudinal study, about how the understanding of different students progresses through Years 3-6.

The formal learning about the senses to which the students in this study had been exposed, although limited, does nevertheless not appear to have produced the outcomes one might desire, suggesting that these students are carrying alternative conceptions that could cause them difficulty later in their education. This appears evidence for the need to revise the approach presently being used, so that the wide experiences and challenges students experience build stronger foundations.

Only then will students appreciate the role of science as a tool for unravelling the mysteries of nature, rather than being a collection of incomprehensible facts. But how might such a revision be accomplished? There appears to be a need for further investigation of how the ideas, of particularly primary children in this age range, are initiated and evolve, and how alternative conceptions might best be effectively challenged.

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