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RESEARCH REPORT
Methods and issues of teaching and learning

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A LANGUAGE PROBLEM REVISITED

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ABSTRACT: A study of twenty years ago showed the extent of the problems associated with the misunderstanding of common language used in a science context. This present sample study indicates that the problems have not gone away. It also reveals that the problems are even greater for pupils whose second language is English. The study goes on to explore the underlying psychological problems caused by language blockages and attempts to measure their effects. The findings are, that pupils, struggling to learn science in a second language, lose at least 20% of their capacity to reason and understand in the process. This has a serious message for countries which, for otherwise good reasons, teach their pupils through the medium of English rather than in the native language. This message also applies to those who have to teach mixed language groups. [*Chem. Educ. Res. Pract. Eur.*: 2001, *2*, 19-29]

KEY WORDS: *common language in a science context; mixed-language group teaching; science learning in a second language; information processing*

Are you and your pupils talking the same language? Is there a problem and what are the consequences for learning in science?

INTRODUCTION

About twenty years ago a number of publications appeared (Cassels & Johnstone, 1978, 1980, 1983, 1985) describing the problems of language in the learning of science. The findings indicated that the technical language of science posed a problem of unfamiliarity, but pupils were seen to be able to cope reasonably with this. Where a more acute problem lay, was in the use in science of normal, familiar language in a highly specific, often-changed and unfamiliar way. A simple word like "pure" (clean or safe) takes on a new meaning in chemistry. "Mass" (a lot, or even a religious service) becomes something different in physics. "Concept or conception" in some circumstances is an idea, but in others it is connected to birth. Even a word like "audible" which one would expect to remain stable in meaning is linked, in the minds of pupils, with a make of car (Audi) or with the sound-alike word "edible".

Studies were done on 16,000 pupils from first to sixth form across the U.K. to establish the comprehension of 95 words in four contexts to establish the extent of the variability of potentially confusing words in everyday and in scientific situations. The words were chosen from earlier work done by Thorndyke et al (1944) and Gardner (1972). This work was published (Cassels & Johnstone, 1985; Johnstone, 1988) and widely circulated through the Royal Society of Chemistry and by the Southern Examining Group to all examiners in the U.K.

Spinning off this work, were a series of unpublished findings about the added effect of these language problems on pupils whose first language was not English. Of the 95 words tested, the vast majority showed that their comprehension was more difficult for non-English native speakers in most contexts.

This might not be a surprising result, but how serious a problem is it? One of us (D S) is a teacher in a country where children, brought up in a language and a culture very different from English, are taught science entirely in English. Government for a number of apparently good reasons supports this policy, but the attainment in science is generally abysmal. This is not an unusual situation in Commonwealth countries (Pollnick & Rutherford 1993).

We set out to do two things:

(i) to repeat, in small scale, part of the Cassels *et al* work, to see if things had changed over the twenty years for second-language pupils and,
(ii) to try to measure the extent of the potential learning barrier resulting from operating in a second language.

Repeating the Survey

This small experiment was conducted in a large Scottish school where half of the pupils had English as first language and the others came from various other language backgrounds. The age of the pupils was 15-16. From the sample of 95 words used in the original work (Johnstone, 1985), 25 words were chosen to resample the situation. These were words which a science teacher would use naturally assuming that the pupils would readily understand them. Almost certainly, if the teacher asked the pupils, "Do you understand the meaning of the word "efficient" the pupils would have said, "yes". But were their understanding and the teacher's understanding the same?

Table 1 shows the facility values (FV = fraction of the class making the correct choice) for each word and also the commonest distracters (wrong meanings). The situation for the first language and second language pupils is set out separately. The set of questions appears in Appendix A.

An inspection of the table of results shows the following patterns.

1. In 23 out of the 25 questions, the FV for 1st language pupils is higher than the FV for the 2nd language pupils. In the cases marked * the FVs were significantly different at better than the 5% level. The fact that about a quarter of the words scored almost the same in both groups indicated that they were not dissimilar in overall ability.
2. Distracters, which offered a "sound alike" or "look alike" word, were popular. For example, "affect" for "effect", "contract" for "contrast", and "admit" for "omit".
3. Some strong distracters had exactly the opposite meaning to the word under test. For example, "source" was given as "where it went to" and "abundant" indicated "shortage".
4. Some responses showed "woolliness" in their meanings indicating imprecise use of words, which have a precise meaning in science. "Limit", "percentage" and "Maximum" all appeared as "average".

TABLE 1: *Comparison of performance of pupils for whom English is the first or second language.*

Word	Facility Value 1St Lang N= 28	FacilityValue 2nd Lang N= 24	Sig. Diff	Attractive Distracters
Limit	0.89	0.63		Average
Average	1.00	0.96		
Accumulate	0.61	0.38		Accommodate
Effect	0.75	0.50		Affect
Disperse	0.96	0.54	*	Stayed in the ground
Contrast	0.89	0.79		Contract
Composition	0.69	0.29	*	All options almost equal (2nd)
Source	0.89	0.75		Where it went to
Simultaneous	0.71	0.54		Similar, Simulate
Consistent	0.64	0.33	*	Constituent, Consolation (2nd)
Adjacent	0.54	0.46		Opposite (1st 0.32) Identical (2nd 0.33)
Illustrate	0.96	0.83		
Isolate	0.93	0.42	*	Operate
Classify	0.96	0.92		
Omit	0.43	0.38		Admit (0.25), Submit (2nd)
Percentage	0.89	0.92		Average
Abundant	0.32	0.46		Shortage
Disintegrate	0.61	0.58		Disappear
Essential	0.93	0.78		Efficient
Estimate	0.96	0.88		
Proportion	0.71	0.33	*	Proposal
Efficient	0.64	0.33	*	Sufficient
Reference	0.79	0.50	*	Remnant
Maximum	0.61	0.38		Average
Initial	0.36	0.21		Crucial (both) Last/End (2nd)
Mean FV	0.75	0.56		
Range	40-100	30-80		
SD	0.15	0.11		

All of these patterns were seen in Cassels' original work (Cassels 1983) indicating that, even in this small sample, the same problems still exist and the differences between 1st and 2nd language pupils are still evident.

The general misunderstandings of all pupils are alarming, but the situation with 2nd language pupils is even more serious.

THE EFFECT OF SECOND LANGUAGE ON THE POTENTIAL FOR LEARNING

Cassels & Johnstone (1983) suspected that the language differences would potentially have a general effect on learning. Although their work was on words in different contexts, it seemed likely that there would be underlying psychological factors, which would affect a pupilis capacity to learn in the medium of the less familiar language.

The fact that the foreign pupils performed less well than the native pupils in our test, and in that conducted by Johnstone and Cassels in 1987, could be taken to indicate that the former were unfamiliar with, and therefore confused by, the different contexts in which English words are used either in science or everyday purposes. An observation has been made (DS) that learning through the medium of English, for instance, poses problems for students whose mother-tongue is not English (Pollnick & Rutherford, 1993). Researchers have gone on to look for explanations as to why the use of an unfamiliar or second-language leads to misapprehension for the learners. Generally, the mediocre performance of second-language learners has been explained by linguistic and psychological effects.

Linguistic effects are a result of one's lack of knowledge of grammar, rules of syntax as well as meanings of words used in their different contexts. First language learners are exposed to inherent and informal methods of learning their language at an earlier stage than their second-language counterparts. They, therefore, have an advantage of learning to apply rules of syntax early in life. This knowledge of application of rules of syntax is said to lead to the ability to "chunk" English text (Klatzky, 1980). Words forming units or chunks according to the rules of syntax also form units of meaning, according to Howe (1970). Poor knowledge of these rules puts second-language learners at a disadvantage of being less able to see meaning in texts.

Being frustrated by failure to see meaning in texts, these learners then resort to rote-learning, a meaningless endeavour involving lack of linkage between new and old information. Very little is then stored permanently in memory since what is learned by rote is easily forgotten. Odhiambo (1972) also stated that most African children studying science, resort to learning by rote simply because what is presented to them as science is alien to their ordinary circumstances and life. This is, of course, a cultural dimension not to be ignored because it forms a substantial part of the prior knowledge of the learners. If the new ideas do not fit with those already held then confusion sets in.

To obtain some framework for measuring the effects on the operational learning processes, recourse was made to an Information Processing Model for learning shown in Figure 1.

The new material is presented to the learner and some filtration is applied to it. Familiar, interesting or attention catching components are admitted through the sensory filter. However, the judgement of what is familiar must be controlled by what the learner already knows, enjoys or believes. In other words, what is already established in Long-Term Memory controls the operation of the filter. What one knows controls what one selects for learning.

The filtered material enters a Working Space, a conscious part of the mind, where the learner tries to make sense of the material by operating on it, reordering it and associating it with what has been retrieved from Long Term Memory. In this way the material is prepared for storage in Long Term Memory or, if it is deemed to be unimportant, it is rejected (forgotten).

The Working Space has a dual function of holding the input material and processing it. Its other characteristic is that it is of limited and fixed capacity for an individual (Baddeley, 1999).

If the Working Space has too much to hold, it has little room left for processing and conversely, if it has too much processing to do, it can hold little information. This clearly has implications for learning.

If the learner is faced with tasks requiring much processing, then little space is left for holding information. Learning material couched in complex, unfamiliar language requires a lot of room in the Working Space to transform it to an understandable form. This may be due to the fact that more "transformation" or translation stages are required for simplifying the material to make it understandable.

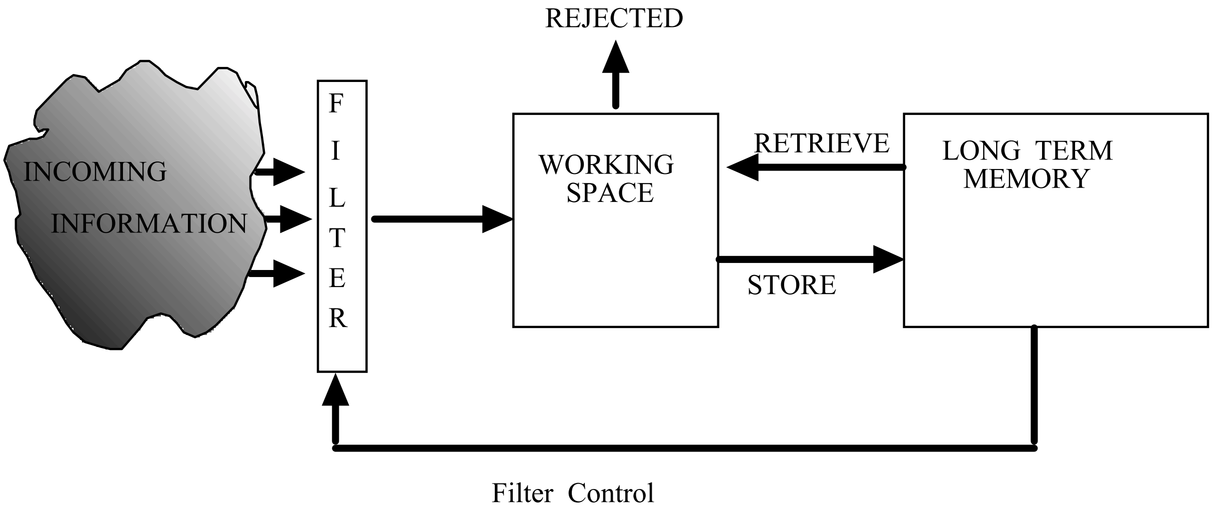

Fig 1. Information Processing Model

This process of simplifying the material takes up so much space that very little is left for holding the information, which can be later transferred to Long Term Memory. As a result, very little ends up being learned.

This suggests at least one important factor to explain why science is found to be a difficult subject by many students because its language requires too much processing. It is also no wonder that there is mediocrity in the performance of some second-language learners in science. They are faced with an even more complex task of dealing with the processing of two unfamiliar languages, that of science and that which is used as the medium of instruction. What then passes to Long Term Memory may be quite minimal or transient.

Based upon this hypothetical model, the following experiment was carried out. Sixtynine 15-year-old pupils, who had been studying French for three years, were given tests in English and in French to establish the size of their Apparent (Available) Working Space in the two language situations. These were Digit Span Tests (Jacobs, 1887) which have been in use for many years.

In these tasks, the subjects were asked to listen to and then write down different lengths of taped sequences of numbers read out in English in the first test, and then in French in the second test, given a month later. In the Digit Forward test, the subjects were asked to write down the number sequences in the exact order in which they had heard them being read out. In the Digit Backward test, however, they were asked to reverse the number sequences in their minds and then write them down, in this new order. The sequences ranged from two to nine digits and were identical in both the English and French versions. It was anticipated that the Backward test would be more difficult than the Forward test as it introduced an extra processing procedure (reversal). For both the Digit Forward and the Digit Backward tests the difference in the mean Apparent Working Space exhibited by the group for the two languages was calculated. Because the Forward test was used as a "warm-up" to familiarise pupils with the procedure, we use here only the results of the Backward test. (The Forward test would have been testing short-term memory.) The Available Working Space for each subject was taken to be the highest number of digits they could remember in the correct order.

In this study, the Working Space is referred to as the Apparent (Available) Working Space (AWS) because it is not necessarily the maximum amount of working memory capacity the subjects might possess. What is measured is indicative of the amount of memory space the subjects managed to utilise effectively in the tests to hold and process (reverse) the information, the rest being unavailable due to other processing factors. The fact that this measured capacity (AWS) was seen to change depending on the nature of the task, shows that it cannot be the actual Working Space, which, according to literature (Baddeley, 1999), is fairly stable. It was anticipated that when the test was done in an unfamiliar language (French), space would be taken up with translation, or holding the numbers in an unfamiliar form, which would reduce the space for holding and processing the digits, and so the Available Working Space would diminish compared with the performance in a more familiar language (English), which needed no translation. Figure 2 serves to illustrate this.

Several studies (Johnstone & El-Banna, 1986; Johnstone & Al-Naeme, 1991) have shown a direct relationship between Working Space, measured by Digit Span tests, and measures of ability in science as measured by conventional examinations.

If our present experiment showed changes in Available Working Space as a result of less familiar language, it would be reasonable to expect that this would affect learning in science.

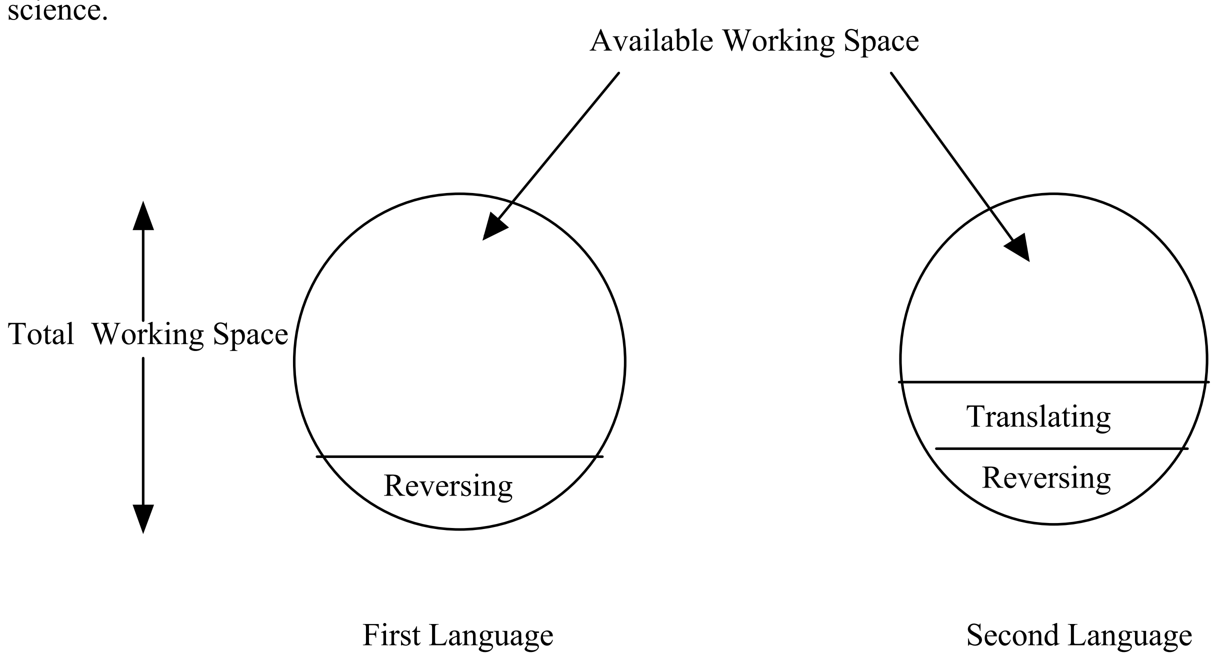

Fig 2. Reduction of available working space due to a second language

RESULTS

Table 2, shows the number of pupils having different Apparent (Available) Working Spaces in the Digit Span Backwards tests in English and French.

TABLE 2: *Frequency table for apparent working space.*

Apparent Working Space	English	French
0	-	3
2	-	1
3	-	15
4	12	13
5	15	19
6	18	15
7	13	2
8	8	1
9	3	-

There is clearly a shift to lower values on moving from English to French. The mean value for AWS in English was 6.0 and in French was 4.4; giving a mean reduction of 1.6 units in Working Space on moving from the native to the non-native language. This represents a drop of just over 25% in available Working Space for the *average* pupil. For pupils of lower inherent working space, a drop of between one and two units represents an even greater percentage reduction. In the table above, some pupils registered zero Apparent Working Space, which indicates a "giving up" on the French test.

The pupils were very familiar with French numerals one to nine, but under the conditions of the test, some seemed to suffer a catastrophic overload and opt out.

Looking at the results for individual pupils, there was almost no case in which a pupilis score in the English test was not higher than in the French test.

If reduction in AWS is related to a poorer ability to process new information into a storable form for Long Term Memory, learning will suffer. Kyllonen (1990) showed a correlation between reasoning skill and Working Memory Space and that the reasoning power was adversely affected by unfamiliarity of language.

There is evidence, among second language learners, of a high level of pure rote learning. This could be a strategy to overcome the lack of AWS by attempting to cut out the kind of processing, which leads to meaningful learning. This would ease the mental discomfort of working in an AWS already restricted by the language problem, but would result in inferior learning. Rote learning without meaning is also likely to be transient.

The model suggests a mechanism to account for some of the poorer performance in language tests. It also indicates the magnitude of the problem facing a pupil trying to learn science in a second language. We are aware that performance in aural and written language is not the same, but our tests have involved both, and have shown an underlying problem in both.

CONCLUSIONS AND RECOMMENDATIONS

1. Teachers with any class must be careful to check that "obvious" words have a meaning, which is shared by pupils and teachers.
2. For classes with an ethnic mix, this procedure has to be even more carefully applied.
3. Explanations in pupils' own words should be encouraged, to avoid the mere "parroting" of rote-memorised, teacher language. In this way pupils and teachers can arrive at shared meaning.
4. Countries which teach science in the non-native language, should be aware of the balance which has to be struck between overcoming problems about textbooks and external examinations and the poor quality of learning in science experienced by many of their pupils, whose mental Working Space is so drastically reduced by operating in an unfamiliar language.
5. Examiners, especially those setting "overseas" papers, must be especially careful about the complexity of the language they use if their measures of science ability are to be valid.

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APPENDIX: THE SET OF LANGUAGE QUESTIONS USED IN THIS STUDY

1. The speed **limit** was 40 mph. This means that cars had to travel

   A at not more than 40mph.
   B at exactly 40mph.
   C between 35 and 45 mph.
   D at an average of 40mph

2. The rainfall was **average** for May. This means that it was

   A the highest ever for May.
   B about normal for May.
   C the lowest ever for May.
   D higher than any other month.

3. Which sentence uses the word **accumulate** correctly?

   A The cars accumulate as they go down the hill.
   B The crowd accumulate the goal scorers.
   C The classroom would accumulate 30 students.
   D The falling leaves accumulate in corners of the garden in Autumn.

4. Which one of the following sentences uses the word **effect** correctly?

   A The teacher could not effect the work of the students .
   B The effect of heating water is that it boils.
   C It took considerable effect to move the boulder.
   D He thought that his smiling would effect everyone.

5. The crowd was able to **disperse** after the football match was over. This means that the crowd

   A chanted and sang.
   B caused no trouble.
   C went away in all directions.
   D stayed in the ground.

6. Which of the following sentences uses the word **contrast** correctly?

   A The painter used black beside white as a contrast.
   B The contrast lines on the map show where the hills are.
   C Many short stories were contrasted to make the book.
   D As the metal cooled rapidly, it was seen to contrast.

7. Which sentence uses the word **composition** correctly?

   A There was no composition on the price for senior citizens.
   B The composition of the bricks depends on the materials used to make them.
   C School is not composition when you are seventeen years old.
   D The guard dog roamed the composition round the factory.

8. The explorers knew the **source** of the river . This means that they knew

   A its length.
   B where it went to.
   C its breadth.
   D where it began.

9. Which sentence uses the word **simultaneous** correctly?

   A Stick insects try to simultaneous twigs to avoid being seen.
   B The teamsí appearances were so simultaneous that it was difficult to tell them apart
   C The two explosions were simultaneous and sounded like one.
   D After the teacherís simultaneous of the problem, the student understood how to solve it.

10. Which sentence uses the word **consistent** correctly?

    A Hydrogen was a consistent of the mixture.
    B The Member of Parliament met a consistent in London.
    C The opinions of the three doctors about the patient, were consistent.
    D She came a very close second in the competition and received the consistent prize.

11. The girls sat in **adjacent** seats. This means that the seats were

    A next to each other.
    B opposite each other.
    C as far apart as possible.
    D identical in every way.

12. This chapter will **illustrate** the point made in the last chapter. This means that it will

    A gloss over the point.
    B contain more paragraphs.
    C leave out the point.
    D make the point clearer.

13. The hospital had to **isolate** the man with the infectious disease. This means that the hospital

A gave him an injection.
B operated on him immediately.
C had to find out the cause.
D put him completely by himself.

14. **Classify** the collection of sea shells. This means

A clean them
B count them
C put them in similar groups
D paint them with varnish

15. Which sentence uses the word **omit** correctly?

A He was not prepared to omit that he had been wrong.
B The seaman saw the arrival of the bird as a good omit
C As the time was short, she decided to omit the last piece of homework.
D It was possible to omit the student to the class because of the circumstances.

16. The exam was a **percentage**. This means that it was

A given to all students.
B a large number.
C the average of the class.
D out of one hundred.

17. The apples were **abundant** last year. This means that

A they were larger than normal.
B there was a shortage of them.
C they were ready for picking earlier.
D there were plenty of them.

18. When cauliflower is boiled for too long it **disintegrates.** This means that it

A disappears.
B changes colour.
C breaks up into smaller pieces
D dries out rapidly.

19. Which sentence uses the word **essential** correctly?

A The dress designer decided that it was more essential to use the electric scissors.
B He used essential jam in his sandwich, which ran out as he bit it.
C The painter thought he had essential paint to finish the job.
D It is essential to wear a seat belt when driving a car.

20. Which sentence uses the word **estimate** correctly?

A Khalid used his dictionary to estimate the answer.
B A clock can estimate the time.
C Many plants grow well in the warm sheltered corner of the estimate.
D For rolls of wall paper was her estimate to cover the walls of the room.

21. Which sentence uses the word **proportion** correctly?

A He chose another proportion of the delicious pie.
B In the drawing, the figures and buildings were in proportion.
C He made a proportion of marriage to the girl.
D The chairperson made a proportion to the shareholders.

22. Which sentence uses the word **efficient** correctly?

A Children need to eat efficient food to grow strong and healthy
B The man did not eat fresh fruit and vegetables and, as a result , he was efficient in vitamins.
C Large brooms are more efficient than small ones for sweeping the yard.
D The man did not have efficient qualifications for the job.

23. Which sentence uses the word **reference** correctly?

A The man in charge of the match was a good reference.
B At the ceremony, the rituals were performed with much reference.
C The reference of the materials was just enough to make a dress.
D During our hill walk we made reference to the map.

24. Which sentence uses the word **maximum** correctly?

A The lazy student used the maximum effort in his work.
B The team won the maximum number of points and so were relegated.
C When she sold her car she wanted to make the maximum profit.
D By dividing the total number of points by the number of students who sat the test, the examiner was able to work out the maximum score.

25. The student enjoyed the **initial** part of the lesson most of all. This means that she enjoyed

A the last part.
B the crucial part
C the first part
D the group work

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