A REVISED GENERATION OF THE TAXONOMY OF OUTPUT MODALITIES

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Summary: The paper presents the final version of the generation of the taxonomy of output modalities for the representation of information in the media of graphics, acoustics and haptics. An earlier published version of the generation has been found to be flawed in several respects. The new generation remedies the flaws and results in a transparent formulation of one of the core constructs of Modality Theory.

Keywords: Interface output modalities, multimodal systems, taxonomy, usability engineering, representations, modality theory, virtual reality.

1. INTRODUCTION

Modality Theory pursues the following objectives, listed in order of increasing complexity:

1. To establish a taxonomy and a set of related categorisations of the generic modalities which go into the creation of multimodal output representations for human-computer interaction (HCI). This should enable:
2. the establishment of sound foundations for describing and analysing any particular type of unimodal or multimodal output representation relevant to HCI;
3. to establish sound foundations for analysing input modalities and entire interactive computer interfaces;
4. to develop a methodology for applying the results of the steps above to the analysis of the problems of information-mapping and information-transformation between work/task domains and human-computer interfaces in information systems design;
5. to use, if possible, results of the work described in building design tools for the support of usability engineering.

These objectives form the research agenda of Modality Theory which addresses the following general information-mapping problem: *Given any particular set of information which needs to be exchanged between user and system during task performance in context, identify the input/output modalities which constitute an optimal solution to the representation and exchange of that information* (Bernsen 1993a, 1994a). Modalitites thus are physically realised 'ways of representing information' and should not be confused with the sensory modalities of psychology. To physically represent information, a medium of representation must be used, and Modality Theory analyses representational output modalities realised in the three media of graphics, acoustics and haptics.

The taxonomy of uncombined or *unimodal* output modalities is a core construct in Modality Theory (cf. Objective (1) above). *Multimodal* modalities for the representation of information are created by combining unimodal modalities. If we understand the relevant properties of all possible unimodal modalities for the representation of information in the three media of graphics, acoustics and haptics, and if we understand the rules for combining unimodal modalities into multimodal modalities for the representation of information, we have a principled theoretical handle on that part of Modality Theory which deals with output modalities in those three media. To answer the question of what are the possible output modalities in the media of graphics, acoustics and haptics, these modalities were generated from the following sets of basic properties (Bernsen 1994b): *linguistic/non-linguistic, analogue/non-analogue, arbitrary/non-arbitrary, static/dynamic*. In addition, as mentioned, distinction is made between the *media of expression* of graphics, acoustics and haptics. The sets of basic properties were chosen such that it is evident that their presence in or absence from a particular representation of information makes significant differences to the usability of that representation for some specific human-computer interface design purpose. For instance, the same linguistic information may be represented in either the graphical, acoustic or haptic medium but the choice of medium strongly influences the suitability of the representation for a given design purpose and is therefore considered a choice between different modalities.

The taxonomy generation itself is purely mechanical and produces 48 basic property combinations which have been published as the matrix represented in Table 1 (Bernsen 1994b). Table 1 uses abbreviations to represent the basic properties mentioned in the preceeding paragraph. The sense of the abbreviations should be immediately apparent but otherwise see Tables 4-6 below which also explain the numbers that occur in the 'modality'-column. Based on the matrix, a reduced set of modalities were derived, which form the subject of current analytical work. Modalities characterised at the level of generality of the matrix are called *generic* (unimodal) *modalities*. This is to indicate that they are still too general for being used as a collection of unimodal modality tools in an 'interface designer's toolbox'. The reason is that a number of important distinctions among different unimodal modalities have not yet been made at the generic level. For instance, analogue static graphic *images* cannot be distinguished, at the generic level, from analogue sta-

	modality	li	-li	an	-an	ar	-ar	sta	dyn	gra	aco	hap
1		x		x		x		x		x		
2		x		x		x		x			x	
3		x		x		x		x				x
4		x		x		x			x	x		
5		x		x		x			x		x	
6		x		x		x			x			x
7	**1**	x		x			x	x		x		
8		x		x			x	x			x	
9		x		x			x	x				x
10	**2**	x		x			x		x	x		
11	**3**	x		x			x		x		x	
12	**4**	x		x			x		x			x
13		x			x	x		x		x		
14		x			x	x		x			x	
15		x			x	x		x				x
16		x			x	x			x	x		
17		x			x	x			x		x	
18		x			x	x			x			x
19	**5**	x			x		x	x		x		
20		x			x		x	x			x	
21		x			x		x	x				x
22	**6**	x			x		x		x	x		
23	**7**	x			x		x		x		x	
24	**8**	x			x		x		x			x
25			x	x		x		x		x		
26			x	x		x		x			x	
27			x	x		x		x				x
28			x	x		x			x	x		

29			x	x		x			x		x	
30			x	x		x			x			x
31	**9/10/11**		x	x			x	x		x		
32			x	x			x	x			x	
33			x	x			x	x				x
34	**12/13/14**		x	x			x		x	x		
35	**15/16/17**		x	x			x		x		x	
36	**18/19/20**		x	x			x		x			x
37	**21**		x		x	x		x		x		
38			x		x	x		x			x	
39			x		x	x		x				x
40	**22**		x		x	x			x	x		
41	**23**		x		x	x			x		x	
42	**24**		x		x	x			x			x
43	**25**		x		x		x	x		x		
44			x		x		x	x			x	
45			x		x		x	x				x
46	**26**		x		x		x		x	x		
47	**27**		x		x		x		x		x	
48	**28**		x		x		x		x			x
	modality	**li**	**-li**	**an**	**-an**	**ar**	**-ar**	**sta**	**dyn**	**gra**	**sou**	**tou**

Table 1. The full set of (48) combinations in the taxonomy. The 28 rows in dark shading are empty, in some cases for several reasons: 1-6 and 25-30 because analogue representations cannot sensibly be used arbitrarily; 2-3, 8-9, 14-15, 20-21, 26-27, 32-33, 38-39 and 44-45 because sound and touch are dynamic; 1-6 and 13-18 because language is non-arbitrary. / between two modalities indicates that the difference between them is based either on prototypes or on the issue of data abstraction. (From Bernsen 1994b).

tic graphic *graphs* but, to an interface designer, these two modalities are being used for very different purposes in representing information. In another example, static graphic written *text* is useful for rather different purposes than is static graphic written *notation*. In consequence, we have developed a more fine-grained level of the taxonomy of output modalities which is called the *atomic level* and the modalities represented at this level are called *atomic modalities* (see further Figure 1 below). The atomic level is intended for use as an 'interface designer's toolbox' and will be published shortly.

However, since the publication of the matrix in Table 1, I have become aware of a number of problems, not in the mechanical generation of the taxonomy itself but in the way this matrix was analysed and 'pruned' or reduced to produce the final set of generic unimodal modalities. This paper presents a resolution to these problems and results in a clean, step-by-step generation of the taxonomy of unimodal modalities.

2. THE DERIVATION PROBLEMS

The first problem about the matrix in Table 1 comes from the rows in dark shading. These rows are claimed to be necessarily empty for one reason or another. But why are these empty rows there in the first place? A proper, scientifically grounded generation of output modalities, it might be claimed, should not generate impossible modalities or impossible combinations of basic properties. Why are there so many empty rows? A colleague in the AMODEUS II project asked: If there has to be so many of impossible modalities then maybe the final generic level taxonomy could be derived more directly on a different basis (Phil Barnard, personal communication)? It is, of course, still possible that the taxonomy might be derived in alternative ways, although I doubt it. But the questions raised are genuine ones.

The second problem derives from rows 31, 34, 35 and 36. Each of these rows contains more than one generic modality as indicated in the 'modality' column, which should be strictly impossible given the principles of taxonomy generation. This problem is not so serious, though. The reason is that, as presented in Table 1, these rows do *not* express 'real' generic modalities but manage to smuggle in additional distinctions which properly belong to the more specific atomic level of the taxonomy. For instance, in row 31, which is defined through its basic properties as analogue static graphics, the modalities 9, 10 and 11 are static diagrammatic pictures, static non-diagrammatic real-world pictures and static graphs, respectively. What is wrong is that the basic properties needed to define and distinguish between these analogue static graphic modalities have not been introduced at the generic level. In other words, an appropriately generalised description of each triplet of modalities in rows 31, 34, 35 and 36, respectively, will solve the problem (cf. Table 6). The important distinctions made prematurely at the generic level may then be, and indeed have been, re-introduced at the atomic level (cf. Figure 1).

Having thus indicated the solution to the second problem, let us return to the first one. We now know that the rows in dark shading in Table 1 represent several inaccuracies. Thus it is claimed in the legend to Table 1 that analogue representations and linguistic expressions, both of which are non-arbitrary, cannot sensibly be used arbitrarily. Non-arbitrary modalities are modalities whose interpretation is possible based on already existing systems of meaning. As stated, the claim that non-arbitrary representations cannot sensibly be used arbitrarily is plainly false. We have all experienced such uses of non-arbitrary representations of information, as when in a children's game a rule is laid down to the effect that one should always say 'yes' when one actually means 'no', and vice versa. The same happens when spies agree that specific words or phrases on the radio, say, serve as agreed-upon calls to action even though the nature of the action is in no way indicated by the ordinary meaning of those words or phrases. The whole point of these exercises precisely is *not* to indicate the nature of the action by the meaning of the words or phrases used. Analogue representations such as images may be used instead of words of phrases. If, for instance, a graphic interface designer lets iconic images of apples refer to ships on a screen map rather than using iconic images of ships for this purpose (assuming that the ships do not carry apples, etc.), we have another case of using non-arbitrary representations arbitrarily. The result would be terrible interface design, but that is another matter. So, analogue representations and linguistic expressions *can* be used arbitrarily in sensible, but sometimes highly problematic, ways.

Table 1 assumes that acoustics and haptics are dynamic media, i.e. that all representational modalities in those media are dynamic modalities. Now, for instance, haptic Braille text is a perfectly static modality even though you may have to move your fingers around somewhat to decode it. This distinction between the modality itself and the kinaesthetics needed to decode it had not been properly worked out at the time when Table 1 was created. Acoustic modalities all seem to be dynamic all right. However, since the creation of Table 1 we have decided, on usability grounds, on a distinction between static and dynamic representations which is not purely physical. According to the new distinction, a modality is static also when it exhibits short-duration repetitive change. Thus, for instance, an acoustic alarm signal which sounds repeatedly until someone switches it off, is considered static rather than dynamic. 'Static', in this sense, means something which allows users *freedom of perceptual inspection* of the representation rather than something which, from the point of view of human perception, does not exhibit perceptible short-term change. In other words, acoustic modalities may on occasion be static rather than dynamic.

Clearly, the taxonomy of generic unimodal modalities, once generated, should be reduced or pruned in a way which takes into account the flaws pointed out above. This will be done in the next section.

3. A CLEAN DERIVATION OF THE TAXONOMY

Just like Table 1, Table 2 presents the matrix of 48 unimodal modalities which has been mechanically generated from basic properties. However, Table 2 is not biased on any issue to do with analysis, pruning or reduction. All 48 modalities are possible in principle, as in fact they are. A first reduction is presented in Table 3. The 18 modalities which have been marked for removal (dark shading) correspond to 18 of the modalities which were also removed in Table 1, namely the arbitrarily used (non-arbitrary) analogue and linguistic modalities. However, the reason for their removal is now different. It is that, in a taxonomy of *unimodal output modalities intended to serve the purpose of clear and efficient presentation of information,* such as in the design of human-computer interfaces, the arbitrary use of non-arbitrary representations constitutes a capital sin. It is like wanting to achieve clear and efficient communication by letting ‘yes’ mean ‘no’ and vice versa. The result is massive production of communication errors and ultimate communication failure. The arbitrary use of non-arbitrary representations is no longer claimed to be senseless, however, but to be against the *purpose* of the taxonomy. The taxonomy aims to support designers in making the best use of every representational modality through building on the expressive strengths of each. Classical (or even archaic) cryptography, on the other hand, uses the expressive strength of particular tokens belonging to some representational modality to mislead. In other words, the taxonomy is just not intended to cover cryptography.

The remaining 30 unimodal modalities are presented in a more explicit form in Table 4. Table 4 provides a correct, non-reduced presentation of the taxonomy.

The subsequent reduction of the number of modalities in the taxonomy from 30 to 20 (see Tables 5 and 6) has been done uniquely for practical

	modality	li	-li	an	-an	ar	-ar	sta	dyn	gra	aco	hap
1		x		x		x		x		x		
2		x		x		x		x			x	
3		x		x		x		x				x
4		x		x		x			x	x		
5		x		x		x			x		x	
6		x		x		x			x			x
7		x		x			x	x		x		
8		x		x			x	x			x	
9		x		x			x	x				x
10		x		x			x		x	x		
11		x		x			x		x		x	
12		x		x			x		x			x
13		x			x	x		x		x		
14		x			x	x		x			x	
15		x			x	x		x				x
16		x			x	x			x	x		
17		x			x	x			x		x	
18		x			x	x			x			x
19		x			x		x	x		x		

20		x			x		x	x			x	
21		x			x		x	x				x
22		x			x		x		x	x		
23		x			x		x		x		x	
24		x			x		x		x			x
25			x	x		x		x		x		
26			x	x		x		x			x	
27			x	x		x		x				x
28			x	x		x			x	x		
29			x	x		x			x		x	
30			x	x		x			x			x
31			x	x			x	x		x		
32			x	x			x	x			x	
33			x	x			x	x				x
34			x	x			x		x	x		
35			x	x			x		x		x	
36			x	x			x		x			x
37			x		x	x		x		x		
38			x		x	x		x			x	
39			x		x	x		x				x
40			x		x	x			x	x		
41			x		x	x			x		x	
42			x		x	x			x			x
43			x		x		x	x		x		
44			x		x		x	x			x	
45			x		x		x	x				x
46			x		x		x		x	x		
47			x		x		x		x		x	
48			x		x		x		x			x
	modality	**li**	**-li**	**an**	**-an**	**ar**	**-ar**	**sta**	**dyn**	**gra**	**aco**	**hap**

Table 2. The full set of 48 combinations of basic properties constituting the possible modalities at the generic level of the taxonomy. All modalities provide possible ways of representing information.

	modality	li	-li	an	-an	ar	-ar	sta	dyn	gra	aco	hap
1		x		x		x		x		x		
2		x		x		x		x			x	
3		x		x		x		x				x
4		x		x		x			x	x		
5		x		x		x			x		x	
6		x		x		x			x			x
7	**1**	x		x			x	x		x		
8	**2**	x		x			x	x			x	
9	**3**	x		x			x	x				x
10	**4**	x		x			x		x	x		
11	**5**	x		x			x		x		x	
12	**6**	x		x			x		x			x
13		x			x	x		x		x		
14		x			x	x		x			x	
15		x			x	x		x				x
16		x			x	x			x	x		
17		x			x	x			x		x	
18		x			x	x			x			x

19	**7**	x			x		x	x		x		
20	**8**	x			x		x	x			x	
21	**9**	x			x		x	x				x
22	**10**	x			x		x		x	x		
23	**11**	x			x		x		x		x	
24	**12**	x			x		x		x			x
25			x	x		x		x		x		
26			x	x		x		x			x	
27			x	x		x		x				x
28			x	x		x			x	x		
29			x	x		x			x		x	
30			x	x		x			x			x
31	**13**		x	x			x	x		x		
32	**14**		x	x			x	x			x	
33	**15**		x	x			x	x				x
34	**16**		x	x			x		x	x		
35	**17**		x	x			x		x		x	
36	**18**		x	x			x		x			x
37	**19**		x		x	x		x		x		
38	**20**		x		x	x		x			x	
39	**21**		x		x	x		x				x
40	**22**		x		x	x			x	x		
41	**23**		x		x	x			x		x	
42	**24**		x		x	x			x			x
43	**25**		x		x		x	x		x		
44	**26**		x		x		x	x			x	
45	**27**		x		x		x	x				x
46	**28**		x		x		x		x	x		
47	**29**		x		x		x		x		x	
48	**30**		x		x		x		x			x
	modality	**li**	**-li**	**an**	**-an**	**ar**	**-ar**	**sta**	**dyn**	**gra**	**aco**	**hap**

Table 3. The full set of 48 combinations of basic properties in the taxonomy. The 18 rows in dark shading represent the arbitrary use of linguistic representations (rows 1-6 and 13-18) and analogue representations (rows 25-30). Being non-arbitrary, these representations can only be used arbitrarily for cryptographic purposes. They have been removed from Table 4 below.

SUPER LEVEL CLASSES	GENERIC UNIMODAL LEVEL	NOTATION
I. Linguistic modalities	**1. Static analogue graphic language**	**<li,an,-ar,sta,gra>**
	2. Static analogue acoustic language	**<li,an,-ar,sta,aco>**
	3. Static analogue haptic language	**<li,an,-ar,sta,hap>**
<li,-an,-ar>	**4. Dynamic analogue graphic language**	**<li,an,-ar,dyn,gra>**
	5. Dynamic analogue acoustic language	**<li,an,-ar,dyn,aco>**
	6. Dynamic analogue haptic language	**<li,an,-ar,dyn,hap>**
	7. Static non-analogue graphic language	**<li,-an,-ar,sta,gra>**
	8. Static non-analogue acoustic language	**<li,-an,-ar,sta,aco>**
	9. Static non-analogue haptic language	**<li,-an,-ar,sta,hap>**
	10. Dynamic non-analogue graphic language	**<li,-an,-ar,dyn,gra>**
	11. Dynamic non-analogue acoustic language	**<li,-an,-ar,dyn,aco>**
	12. Dynamic non-analogue haptic language	**<li,-an,-ar,dyn,hap>**
II. Analogue modalities	**13. Static analogue graphics**	**<-li,an,-ar,sta,gra>**

	14. Static analogue acoustics	<-li,an,-ar,sta,aco>
	15. Static analogue haptics	<-li,an,-ar,sta,hap>
<-li,an,-ar>	16. Dynamic analogue graphics	<-li,an,-ar,dyn,gra>
	17. Dynamic analogue acoustics	<-li,an,-ar,dyn,aco>
	18. Dynamic analogue haptics	<-li,an,-ar,dyn,hap>
III. Arbitrary modalities	19. Arbitrary static graphics	<-li,-an,ar,sta,gra>
	20. Arbitrary static acoustics	<-li,-an,ar,sta,aco>
	21. Arbitrary static haptics	<-li,-an,ar,sta,hap>
<-li,-an,ar>	22. Dynamic arbitrary graphics	<-li,-an,ar,dyn,gra>
	23. Dynamic arbitrary acoustics	<-li,-an,ar,dyn,aco>
	24. Dynamic arbitrary haptics	<-li,-an,ar,dyn,hap>
IV. Explicit modality structures	25. Static graphic structures	<-li,-an,-ar,sta,gra>
	26. Static acoustic structures	<-li,-an,-ar,sta,aco>
	27. Static haptic structures	<-li,-an,-ar,sta,hap>
<-li,-an,-ar>	28. Dynamic graphic structures	<-li,-an,-ar,dyn,gra>
	29. Dynamic acoustic structures	<-li,-an,-ar,dyn,aco>
	30. Dynamic haptic structures	<-li,-an,-ar,dyn,hap>
SUPER LEVEL CLASSES	**GENERIC UNIMODAL LEVEL**	**NOTATION**

Table 4. 30 generic unimodal modalities result from pruning of Table 3.

reasons in order to simplify the work involved in using and creating the taxonomy. The presentation and analysis of *static* acoustic modalities is integrated with the presentation and analysis of *dynamic* acoustic modalities, and the presentation and analysis of *static* haptic modalities is integrated with the presentation and analysis of *dynamic*
haptic modalities. The practical reasons are as follows. Static acoustics constitute a relatively small and reasonable well-circumscribed fraction of acoustic representations in whatever acoustic modality. The presentation and analysis of the static acoustic modalities may without loss of information be integrated with that of the dynamic acoustic modalities which constitute the main class of acoustic representations. Similarly, dynamic haptics currently constitute a relatively small fraction of the haptic representations in whatever haptic modality, and haptics is generally not yet well developed as a class of human-computer interface modalities. The dynamic haptics fraction may not be as well cir-

SUPER LEVEL CLASSES	GENERIC UNIMODAL LEVEL	NOTATION
I. Linguistic modalities	1. Static analogue graphic language	<li,an,-ar,sta,gra>
	2. Static analogue acoustic language 5. Dynamic analogue acoustic language	<li,an,-ar,sta,aco> <li,an,-ar,dyn,aco>
	3. Static analogue haptic language 6. Dynamic analogue haptic language	<li,an,-ar,sta,hap> <li,an,-ar,dyn,hap>
<li,-an,-ar>	4. Dynamic analogue graphic language	<li,an,-ar,dyn,gra>
	7. Static non-analogue graphic language	<li,-an,-ar,sta,gra>
	8. Static non-analogue acoustic language 11. Dynamic non-analogue acoustic language	<li,-an,-ar,sta,aco> <li,-an,-ar,dyn,aco>
	9. Static non-analogue haptic language 12. Dynamic non-analogue haptic language	<li,-an,-ar,sta,hap> <li,-an,-ar,dyn,hap>

	10. Dynamic non-analogue graphic language	**<li,-an,-ar,dyn,gra>**
II. Analogue modalities	**13. Static analogue graphics**	**<-li,an,-ar,sta,gra>**
	14. Static analogue acoustics **17. Dynamic analogue acoustics**	**<-li,an,-ar,sta,aco>** **<-li,an,-ar,dyn,aco>**
<-li,an,-ar>	**15. Static analogue haptics** **18. Dynamic analogue haptics**	**<-li,an,-ar,sta,hap>** **<-li,an,-ar,dyn,hap>**
	16. Dynamic analogue graphics	**<-li,an,-ar,dyn,gra>**
III. Arbitrary modalities	**19. Arbitrary static graphics**	**<-li,-an,ar,sta,gra>**
	20. Arbitrary static acoustics **23. Dynamic arbitrary acoustics**	**<-li,-an,ar,sta,aco>** **<-li,-an,ar,dyn,aco>**
<-li,-an,ar>	**21. Arbitrary static haptics** **24. Dynamic arbitrary haptics**	**<-li,-an,ar,sta,hap>** **<-li,-an,ar,dyn,hap>**
	22. Dynamic arbitrary graphics	**<-li,-an,ar,dyn,gra>**
IV. Explicit modality structures	**25. Static graphic structures**	**<-li,-an,-ar,sta,gra>**
	26. Static acoustic structures **29. Dynamic acoustic structures**	**<-li,-an,-ar,sta,aco>** **<-li,-an,-ar,dyn,aco>**
<-li,-an,-ar>	**27. Static haptic structures** **30. Dynamic haptic structures**	**<-li,-an,-ar,sta,hap>** **<-li,-an,-ar,dyn,hap>**
	28. Dynamic graphic structures	**<-li,-an,-ar,dyn,gra>**
SUPER LEVEL CLASSES	**GENERIC UNIMODAL LEVEL**	**NOTATION**

Table 5. The 20 generic unimodal modalities resulting from pragmatic fusion of the static and dynamic acoustic modalities and the static and dynamic haptic modalities. In Table 6 below, the numbering system has been cleaned up.

cumscribed, though, and may be expected to grow dramatically with the growth of haptic output technologies. When this happens, we may simply re-instate the static/dynamic distinction in the haptic modalities part of the taxonomy. Finally, the reason for reducing the total number of generic modality entries is that, once the atomic level becomes added to the taxonomy, the number of atomic modalities can be rather dramatically reduced as a result of the proposed fusions at the generic level. Overall, at the generic and atomic levels combined, the proposed fusions reduce the number of modalities in the taxonomy

SUPER LEVEL CLASSES	**GENERIC UNIMODAL LEVEL**	**NOTATION**
I. Linguistic modalities	**1. Static analogue graphic language**	**<li,an,-ar,sta,gra>**
	2. Static analogue acoustic language **Dynamic analogue acoustic language**	**<li,an,-ar,sta/dyn,aco>**
	3. Static analogue haptic language **Dynamic analogue haptic language**	**<li,an,-ar,sta/dyn,hap>**
<li,-an,-ar>	**4. Dynamic analogue graphic language**	**<li,an,-ar,dyn,gra>**
	5. Static non-analogue graphic language	**<li,-an,-ar,sta,gra>**
	6. Static non-analogue acoustic language **Dynamic non-analogue acoustic language**	**<li,-an,-ar,sta/dyn,aco>**
	7. Static non-analogue haptic language **Dynamic non-analogue haptic language**	**<li,-an,-ar,sta/dyn,hap>**
	8. Dynamic non-analogue graphic language	**<li,-an,-ar,dyn,gra>**
II. Analogue modalities	**9. Static analogue graphics**	**<-li,an,-ar,sta,gra>**

	10. Static analogue acoustics **Dynamic analogue acoustics**	**<-li,an,-ar,sta/dyn,aco>**
	11. Static analogue haptics **Dynamic analogue haptics**	**<-li,an,-ar,sta/dyn,hap>**
<-li,an,-ar>	**12. Dynamic analogue graphics**	**<-li,an,-ar,dyn,gra>**
III. Arbitrary modalities	**13. Arbitrary static graphics**	**<-li,-an,ar,sta,gra>**
	14. Arbitrary static acoustics **Dynamic arbitrary acoustics**	**<-li,-an,ar,sta/dyn,aco>**
	15. Arbitrary static haptics **Dynamic arbitrary haptics**	**<-li,-an,ar,sta/dyn,hap>**
<-li,-an,ar>	**16. Dynamic arbitrary graphics**	**<-li,-an,ar,dyn,gra>**
IV. Explicit modality structures	**17. Static graphic structures**	**<-li,-an,-ar,sta,gra>**
	18. Static acoustic structures **Dynamic acoustic structures**	**<-li,-an,-ar,sta/dyn,aco>**
	19. Static haptic structures **Dynamic haptic structures**	**<-li,-an,-ar,sta/dyn,hap>**
<-li,-an,-ar>	**20. Dynamic graphic structures**	**<-li,-an,-ar,dyn,gra>**
SUPER LEVEL CLASSES	**GENERIC UNIMODAL LEVEL**	**NOTATION**

Table 6. The 20 generic unimodal modalities resulting from pragmatic fusion of the static and dynamic acoustic modalities and the static and dynamic haptic modalities.

by 30 modalities. Table 5 shows the proposed fusions at the generic level. Table 6 presents the final, pragmatically reduced, taxonomy of generic unimodal modalities.

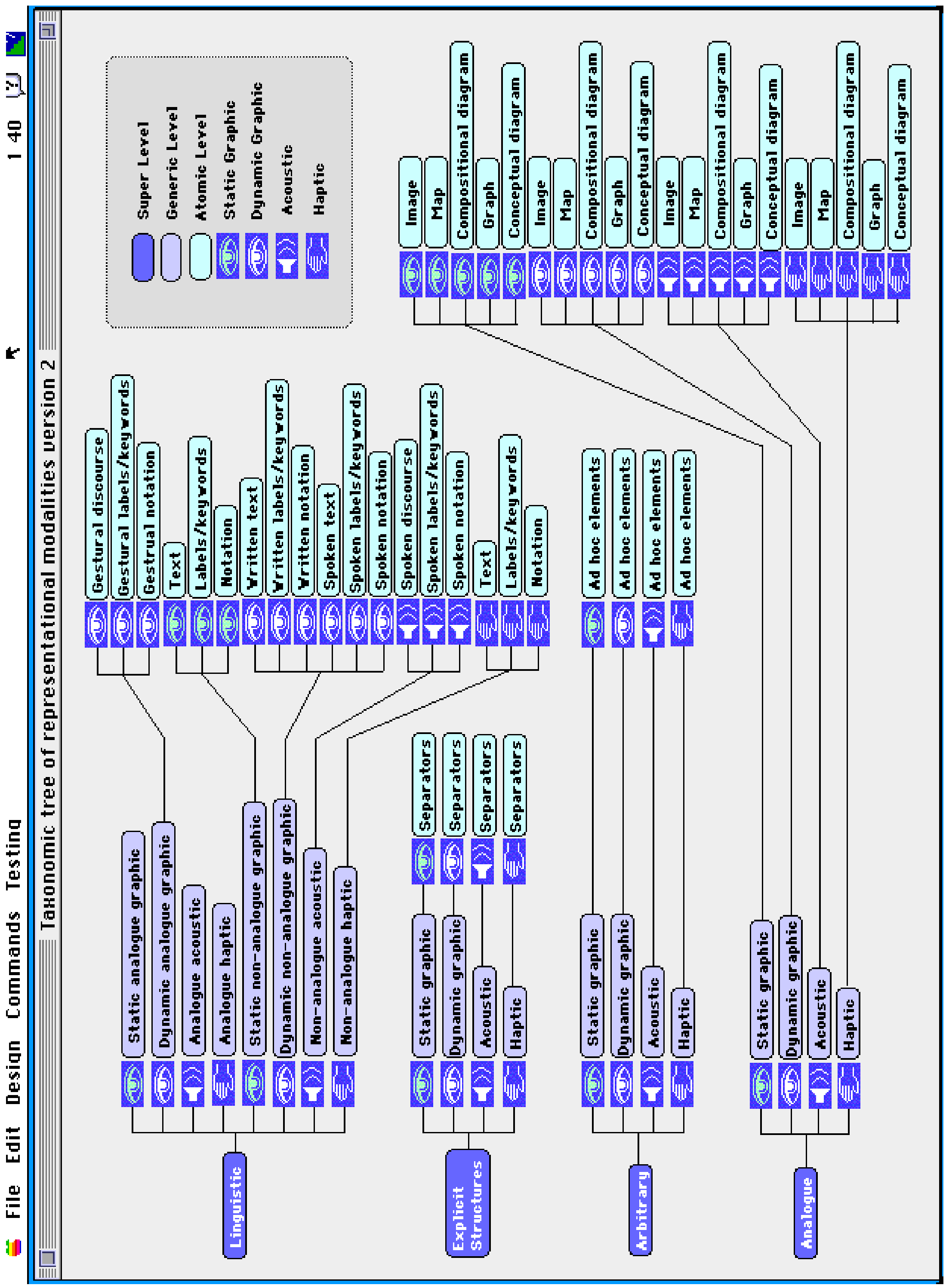

Figure 1. The super level, generic level and atomic level of the taxonomy of output modalities.

From viewing Table 6 it may still not be immediately obvious why the taxonomy cannot be used as a designer's toolbox at the generic level. This point should become obvious from the conceptual diagram in Figure 1 which presents three levels of the taxonomy, i.e. the super level, the generic level and the atomic level. The super level, which has not been mentioned above, merely represents one possible classification of the generic modalities among others and lacks any deeper theoretical significance. The presentation in Figure 1 shows the main screen of the Taxonomy Workbench Version 2 [Bernsen, Lu and May 1994].

4. ONGOING WORK

Our current work on Modality Theory focuses on completing the analysis of output modalities at the super level, the generic level and the atomic level, illustrating and presenting the modalities in the Taxonomy Workbench, and testing the interface design support capabilities of the taxonomy of output modalities through design case studies [Bernsen and Bertels 1993, Verjans and Bernsen 1994]. We are beginning to address 'input modalities' so that work will soon be dealing with all aspects of the research agenda of Modality Theory (cf. Sect. 1 above).

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