punct - An Alternative Verb Semantic Ontology Representation

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Abstract

The goal is to build a verb ontology based on Indian grammatical tradition. We propose here an ontological structure to represent verbs in a language, which can be adapted across languages. This is an ongoing work and presently the method has been applied to develop ontologically informed etymon in English.

1 Introduction

In an ontology based classification, the main criteria for class identification and membership are provided by extra-linguistic events or situations expressed by verb meanings (Lenci, 2010). Since ontology based classifications are concept dependent, they can be used as inter-lingual verb resources (Boas, 2005). The approach put forward here is an attempt to explore the feasibility of arriving at an ontological classification of verbs based on overlapping verb senses. This work is an extension of 'Understanding Verbs Based on Overlapping Verbs Senses (Rajan, 2013)'. In the prior work a new approach for inter-lingual ontological classification of verbs was put forward. This method looks into the inherent meaning of each verb and identifies seven meaning primitives. It is inspired by Conceptual Dependency(CD) theory (Schank, 1972; Schank, 1973; Schank, 1975) and the Indian grammatical traditional thinking of Niruktakāras: "all content words are either verbal roots (activities) or derived from verbal roots".

2 Why Verbs ?

According to Indian Grammatical Tradition, verbs occupy a central role in a language. Consider the following simple sentence (in Sanskrit):

devadattaH pacati
'Devadatta is cooking'.

According to Yāska (c.6th-5th centuries BCE); Nirukta (Sarup, 1920) 1.1:

> The principal meaning signified by the above utterance is the act of cooking - 'pacati' and not the subject - 'devadattaH' (who is predicted to be cooking).

In Pāṇini's derivational system, by means of which utterances (vākya) and their components are accounted for, items assigned the name dhātu 'verb, root' rank as core elements of utterances that are actually usable and serve as a starting point of derivation of such utterances. In the above sentence, cook 'pac' is called the dhātu (root verb) and hence the starting point of derivation. Pāṇiniyas, like Patañjali (second century BCE) unequivocally speak of the meaning of dhātvarthas (dhātu + artha) 'verb meanings' as kriyā 'act, action'.

In Sanskrit, verb is called 'kriyā' and kriyā stands for action or activity. But verb consists of both 'action(kriyā)' and 'state(bhāva)' verbs. The explanations put forward by grammarians in order to accomodate the concept of 'state' into the definition of verb, that is, transition from kriyā-based to bhāva-based definition is given in the following paragraphs.

Bhartṛihari is the first Pāṇiniya to formulate the technical definition of kriyā as given in Pāṇini's grammar.

According to Bhartṛihari (5th century CE):

> Every verb has 'sense of sequence' and 'state' in it. Hence, every verb projects a 'sense of happening', making this sense 'omnipresent' in all verbs.

Basic meaning of Sanskrit word bhāva is 'state, condition'. Word bhāva in P.2.3.37 (Joshi, 1991) is an instance of "a particular state or condition in which an item finds itself as a result of something happening, and also the happening, occurrence itself".

So, we can use word ‘bhāva’ to mean ‘happening’. We have already seen that ‘sense of happening’ is omnipresent in all verbs. That is, ‘bhāva’ is omnipresent or universal in all verbs.

From Indian grammatical tradition we have adopted the concept of *‘universal verb’*. Our original contribution is that we have defined an ‘ontological structure’ to represent ‘universal verb’ and have used it to represent the 7 primary verb senses ‘(puncts[1])’ which we have identified. The structure of bhāva and the identification of 7 puncts are explained in the next two sections.

The goal of this work is to classify *concept* ‘verb/activity’ and not the lexical category ‘verb’ across languages. Verbs belonging to specific languages are collected for this work but they represent ’concepts’. For example ’run’ is a concept meaning ’to go quickly by moving the legs more rapidly than at a walk and in such a manner that for an instant in each step all or both feet are off the ground[2]’. Even if all languages do not have parts of speech they will surely have concepts like ’run’, ’eat’, etc.

3 Ontological Form of Happening

Structure of happening (see Figure 1) consists of two states: initial/state1 and final/state2, and the context within which the change in state occurs.

> ‘Context’ consists of ontological attributes.
> Ontological attributes are: space, location, time, manner, reason which in turn have sub-attributes.
> The Sub-attributes of ‘space’ are : direction - linear, curvilinear, down
> ‘location’ are: source, destination
> ‘time’ are: frequency, duration
> ‘manner’ are: mode, speed
> ‘reason’ are: purpose, cause, etc.

These are called ontological attributes as they are concepts and they can be represented across languages. To explain this point we have taken a sample verb ’run’ in English and its Hindi counterparts ’bhāgana’ and ’daud̠ana’ and shown the mapping in Table 1.

[1]an element held in Whitehead’s philosophy of nature to be analogous to a point in a geometric system - Merriam Webster

[2]http://dictionary.reference.com/browse/run

Table 1: Ontological attribute mapping among verbs in English and Hindi(Indian language)

English	Run	Hindi	dauḍanā	bhāganā
move / do	1	sthāna parivartan karanā / karanā	1	1
Direction(linear):	1	diśā(s̈idhā):	1	1
move along	1	sātha sātha sthāna parivartan karanā	1	1
Speed:	1	raftār:	1	1
fast	1	teja	1	1
Mode:	1	r̈iti(praṇ āli):	1	1
putting one foot in front of the other allowing each foot to touch the ground before lifting up the next	1	ek paira ke Age dōsarā paira is tarah rakhana tāki ek paira jamīna par chūne ke bā da hi dūsarā chuye	1	1
Cause:	0	kāraṇa:	0	1
danger		āpatti		
fear		bhaya		
some reason	0	kuch kāraṇa	0	1

Happening or bhāva can be defined as change of state in a context. Bhāva has a formal structure and has been named ‘punct’ (Singh, 2001).

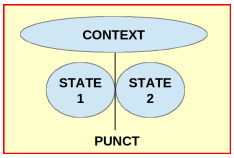

Figure 1: Structure of punct

The formal structure of bhāva/punct is:

$$\langle e1|e2, C\rangle$$

> where e1 stand for entity/state1, e2 for entity/state2, and C represents context / feature-space.

The formal structure is a recursive form as its context itself is made out of other formal structures. The two states in this structure are contiguous [3]. By adding a formal structure as form of contiguity, change transfers to two contiguous but different states and state transforms into combinatory context of happening. Every ‘change of state’ has a location, presence of force or absence of force, result, context and the context itself involves ‘change of state’ in some other context.

[3]Take a verb ‘cook - prepare a dish’. The initial and final states are related to each other.

4 The seven puncts

Two works WordNet (Miller, 1990) and Nirukta (Sarup, 1920) were influential in restricting the number of overlapping verb senses to 7. The WordNet has identified 8 common verbs (have, make, set, get, take, be, run, go). Let us take each verb and analyse it in detail and see how they were modified into 7 primitive verbs senses. The 7 senses are given names following the head word (Levin, 1993) style of nomenclature.

The verbs 'make', 'set', 'take' and 'get' are action verbs. Actions are done by an actor. These actions can take place only if an agent is involved in initiating them, 'My grandmother made a dress for me.', 'Catherine set a chair by the bed.', 'He took seven wickets in the second innings.', 'She got a cake for me.'. So the 'sense of agent' which is known as sense of 'doer' (Sanskrit, sādhya — sādhaka[4] bhāva) is common[5] and is also the primary verb sense in these four verbs. Since 'do-ing' sense is present in all 4 verbs. Here ***'do'*** is a head word (Levin, 1993) to represent all types of agent (both animate and in-animate) initiated actions.

The verb 'have/has' represents possession. Possession can be of three types 1) when a person himself obtains an object, like the verb 'take', 'He took seven wickets in the second innings.' 2) when the agent is the recipient of an object, like the verb 'get', 'I got a letter from him the other day.' and 3) possessing a quality, like the verb 'have','She has got blue eyes.'. Since, 'have', 'get' and 'take' have the verb sense 'possession' in common all the three verbs were grouped under the sense of ***'have'*** (Sanskrit, grāhya — grāhaka bhāva). As an agent should initiate the actions of transferring possessions in the verbs 'take' and 'get' they have possession as the secondary verb sense.

The verb 'be' represents state. Verbs like 'have', 'set' are state verbs. Sentence like - 'He has property. shows that the concerned person is in possession of some property. Having something in possession is a continuous 'state' until it is lost or given away. 'The village was set among olive groves on a hill.', shows the fixed position(state) of a village. The sense of state forms an integral part of the structure of verb. So, ***'be (is)*** (Sanskrit, ādhāra — ādheya bhāva) is a primitive verb sense.

The verbs 'run' and 'go' have sense of 'movement' in the form of linear displacement in them. Verb 'make', 'My grandmother made a dress for me.', has movement in the form of change from initial(raw) to final(finished) state. Verb 'take' has movement in the form of change in the position of an object and its ownership, 'Someone must have sneaked in here and taken it.'. All the different types of movements or changes are together represented by the verb sense ***'move'*** (Sanskrit, pūrva — apara bhāva).

The verbs 'take' and 'get' have a sense of separation of a part from a whole. Both these verbs result in change in the location of objects being possessed or change in the initial and final states of the agent or recipient. Change in location means separation from the initial position, 'The Soviet forces took more than 30,000 Romanian prisoners and all their equipment.'. Change in state means adding or removing or modifying the existing state to a new one, 'Women have fought long and hard to get into positions that men hold within the leadership of the church.'. The verb sense ***'cut'*** (Sanskrit, amśa — amśi bhāva) is used to represent this.

The verbs 'make', 'take', 'set' and 'get' act on limited set of objects. 'Make' means to produce something, often using a particular substance or material[6]. But we can make only a restricted number of objects, 'Shall I make some coffee?'. In order to explain this sense of restriction or limitedness the verb sense ***'cover'*** (Sanskrit, āropya — āropaka bhāva) was included as a primitive verb sense.

One of the definitions of the verb 'make' is 'to bring into existence by shaping or changing material, combining parts, etc.[7]'. For this the doer needs to have knowledge as to how this process has to be done, 'She makes all her own clothes.'. Hence, the verb sense ***'know'*** (Sanskrit, jnāna — jnyeya bhāva) was included as a primitive verb sense.

Using the above mentioned method we have identified 7 mutually exclusive primitive verb senses (puncts) (see Table 2). Using such primitive verb senses and assuming that each verb has these senses we can analyze inherent meaning of different verbs. These seven[8] primitive senses are

[4]Category system followed in vaiśeṣika(system founded by sage kaṇāda circa 150 A.D). The 7 primitives are 7 such categories.

[5]If a sense is 'common', it means that it is found in many verbs. The identification process is explained in this section

[6]http://dictionary.cambridge.org/dictionary/british/make_1

[7]http://dictionary.reference.com/browse/make

[8]ṣaṭ bhāva vikār of vārṣyāyaṇi(Sarup,1920) six types of bhāva are: origin, existence, modification, increase, decay, and destruction has influenced the identification of seven

also known as bhāva-s according to Indian grammatical tradition. This bhāva-s constitutes primitive meaning senses implicit in the meaning of each verb. Term bhāva means happening and this sense overlaps with all verbs. This is also a traditional Indian linguistic claim. These senses are mutually interwoven through their context. For example: The word 'cover' has the verb sense 'cover (wrap/wrapped)' as primary and 'move (before/after)' as secondary verb sense in it. Verbs can have senses ranging from one to all seven in them, but the 7 senses (know, move, do, have, is, cut, cover) are mutually exclusive and are logical structures (Refer Table 2).

The context (C) of each bhāva-s is made of:

> C - [ontological: attributes (feature-space), bhāva (recursive), and any other information which can contribute to meaning disambiguation.]

5 Application

5.1 Annotation Process

Each verb can have all the seven meaning primitives in it. Overlap of verb meaning is illustrated best when meaning of a verb is explicated using another verb or verbs. On analysis, one can see that there is an order in which the verbs are used for explication. This order helps in finding the primary, secondary, tertiary, etc. meaning senses. The order can be found by using two methods. The methods are explained below using two verbs: *dance* and *confuse*.

Example 1:
First Method:

Verbs are mostly polysemous. We collect all the possible meanings of each verb from various resources like dictionaries. Then, we analyse each meaning and place them in different classes (cell in matrix) according to the order of the meaning primitives. The meaning primitives are identified by analysing the inherent meanings of the verbs by posing a series of questions.

Take verb 'dance'.

> Step 1. If a verb is polysemous,
>
> Verb 'dance' has two meanings. Meaning 1: (Of a person) move quickly and lightly

primitives / puncts in this work.

Table 2: puncts and explanations

Primitives (Elementary Bhāva-s/puncts)	Explanation
Know:Sense of knowing (Sanskrit, **jnāna—jnyeya** bhāva) (object of 'know' / the process involved in knowing that object)	Know/Knower Conceptualize, construct or transfer information between or within an animal. E.g. "forget" - to forget something one has to know about it. Forget is a process having state change from knowing to not knowing over a period of time. So,this particular verb has "knowing" as primary sense and change of state/"move" as secondary sense.
Move:Sense of Move /change /process (Sanskrit, **pūrva—apara** bhāva) (state at the beginning of a process / state at the end of the process)	Before/After Every process has a movement in it. The movement maybe a change of state or a change in location. E.g. "fall" - change of position from a higher state to lower state physically or in abstract sense. Actions like falling of leaves do not have a sense of agency, the fall happens on its own. So the word has the sense of 'pure movement'.
Do : Sense of agency (Sanskrit, **sādhya—sādhaka** bhāva) (something to be accomplished /accomplished)	Agent/Action A process which can be accomplished only with a doer. E.g. "cook" - has a sense of someone doing cooking. The process of cooking involves change of state from raw to cooked by a doer. So, it has 'doing' sense as primary and 'move' sense secondary to it.
Have : Sense of possession or having (Sanskrit, **grāhya—grāhaka** bhva) (something that is the object of grasping /to grasp)	Grip/Grasp Possessing, obtaining or transferring a quality or thing. E.g. "like" - To like something one must have prior 'knowledge' about it. Liking is something you "have or possess". Hence 'have' is primary sense and "knowing" is secondary sense.
Be : Sense of state of being (Sanskrit, **ādhāra—ādheya** bhāva) (location/attribute)	Locus/Locatee Continuously having or possessing a quality. E.g. - "confuse" (I am confused). It is a state and it is located in me. 'Be / is' is the primary state and to get confused you must know and have contradictory opinion about the object. So, sense of 'know' is secondary.
Cut : Sense of part and whole (Sanskrit, **amśa—amśi** bhāva) (part of an object or process/whole to which the part belongs)	Part/Whole Separation of a part from whole or joining of parts into a whole. Processes which causes pain. Processes which disrupt the normal state. E.g. - "break" It has a sense of a thing being divided into parts. 'Cut' sense is primary to it and breaking is 'done' by someone so has a sense of agency 'do' as the secondary sense.
Cover : Sense of ascribe and ascription (Sanskrit, **āropya—āropaka** bhāva) (to be attributed/the one to which it is attributed)	Wrap/Wrapped Processes which pertain to a specific object or category. It is like assigning a boundary. E.g. - "guarantee" - when you guarantee you are putting a kind of cover (ascription) on that object so it has 'cover' as primary sense and someone has to do it, and so has 'doing' as secondary sense.

Meaning 2: Move rhythmically to music, typically following a set sequence of steps

Step 2. Take one meaning at a time. Let us take verb 'dance' as in meaning 1.

Step 3. Take a simple sentence in which dance is used in the particular meaning.

'She danced happily into the room.'

Step 4. Instead of 'dance' substitute the meaning and rewrite the sentence.

She did + (move quickly and lightly) + happily into the room.

Step 5. Keep rewriting the sentence using primitives like 'do', 'move', 'have' etc.. so that you can re-write the entire sentence using them. While using primitives see in which order the primitives can be written too.

She DO+past + (MOVE) + quickly and lightly + happily + into the room.

Step 6. In this particular sentence, dance means a type of movement which is done by a person (doer). Hence, 'move' is primary meaning primitive and 'do' is secondary meaning primitive.

Hence we write it as : MOVE/DO

Second method is by nominalising verbs in a simple sentence. For example:

She danced into the room.

Step 1. She did the act of dancing into the room.

Step 2. She did the act of moving into the room dancing.

Step 3. She 'DO+past' (moving into the room) MOVE+ing as if dancing.

Hence we write it as : MOVE/DO

Example 2:
First method for verb 'confuse':
Confuse means 'Make (someone) bewildered or perplexed'

The flood of questions confused me.

Step 1. The flood of questions made me bewildered or perplexed.

Step 2. The flood of questions DID the process of creating bewilderment or perplexity in me.

Step 3. The flood of questions DO the act of creating a STATE of bewilder- ment or perplexity in me.

Step 4. The flood of questions DO the act of creating a 'STATE'of Inability to deal with or understand some- thing in me.

Step 5. The flood of questions DO the act of creating a 'IS' of Inability to deal with or KNOW about something in me.

Hence we write it as : IS/KNOW/DO

In this sentence 'confused' is a state. Confusion is always about some information / knowledge and so is about 'know'. This particular state occurs only in an animate being and hence 'DOer' sense. the order is decided looking at the dependencies of the various senses. Confusion is a state and hence 'IS' is primary. The state is about an information so, 'KNOW' is secondary. This state occurs in an animate being and so 'DO'er sense is tertiary.

Second method for verb 'confuse'

You confuse me

Step 1. you create confusion in me

Step 2. You create confused (state of Knowledge) about something (object of knowledge)in me

Step 3. You 'DO' creation of Confused ('STATE' of 'KNOW' ledge) about something (object of 'KNOW'ledge) in me.

Hence we write it as : IS/KNOW/DO

In the last sentence 'do' is the tertiary sense, 'know' is the secondary sense and 'is' state of knowledge is the primary sense of verb 'confuse'.
Hence we write it as : IS/KNOW/DO

The annotation work consisted of identification of primary and secondary puncts and ontological attributes. Though almost all puncts can be found in every verb, presently we have restricted the identification to two. The verbs were grouped and represented in the form of a two-dimensional 7x7 matrix. The rows and the columns stand for the primary and secondary primitive senses respectively. All verbs in a row were grouped together and ontological attributes of 7 separate groups (7 rows) were identified. Ontological attributes consists of concepts like space, location, time, manner, etc.

Manual annotation was done first for all verbs (2500) in Sanskrit then for verbs in English (3750 - excluding all types of compounds). For Sanskrit, the verb list was collected from many sources. More than 3000 verbs including variations in accentuation were collected from various resources (Apte, 2008; Capeller, 1891; Kale, 1961; Bruno, 1922; Palsule, 1955; Palsule, 1961; Varma, 1953; Williams, 2008) and a new typed list was created in Devanagari script. List was created as such a complete list of Sanskrit verbs was not available online. The list was then annotated manually by one person and cross checked by three Sanskrit experts. For English, the verb list was created from various resources like - Levin's verb list (Levin, 1993) and verbs added to this list as extensions (Dang, 1998; Kipper, 2000; Korhonen, 2004). Meanings of all the verbs in English were

obtained from various online dictionaries (Merriam Webster[9], Oxford[10], Dictionary.com[11], Cambridge Advanced Learners Dictionary[12]). The list was then manually annotated by the same person who had annotated the Sanskrit verbs and the annotation was cross-checked by three annotators.

5.2 Ontology Population: Using English and Sanskrit Verbs

Ideally meaning of a verb involves all seven layers of puncts. However, if we take two or three layers of primitive verb senses in a verb, they would be sufficient to identify meanings of most verbs. We took just the first two senses to demarcate meaning of verbs. The primary and secondary senses of all verbs in English and Sanskrit were identified. They were classified into a two-dimensional 7x7 matrix.

As mentioned in section 3, meaning of a verb also includes context which in turn includes ontological attributes[13]. The approach has similarities with work on use of clustering for finding verb semantics (Sun, 2009).

Ontological attributes[14] of a verb is the set of all 'meaning components (non-linguistic)' which can be used to define its meaning exhaustively and also help in distinguishing it from other verbs. Also, verbs very close in meaning, no matter how close they are, can be distinguished based on the differences in their meaning component set (even if they differ by one component, they differ in meaning). Thus, it is an ontological and computational resource of verbs. For example, 'Leave', 'depart' and 'abandon' are 3 verbs having 'move' sense as primary, cut sense as secondary, and do sense as tertiary. That means all the 3 verbs belong to the same cell / class. In order to differentiate between the 3 verbs in the same class, we identify the ontological attributes.

The process used for identifying ontological attributes is explained below. Collect all possible meanings of all three verbs. Isolate the meanings which have move as primary verb sense.

Table 3: Identification of ontological Attributes

Verb	**Meaning**	**Ontological attributes**
1) Leave	go away from, depart from permanently, go away from a place without taking (someone or something)	move away + from somewhere/ something/ someone + permanently/short time + accidentally/intentionally
2) Depart	Leave, especially in order to start a journey.	move away + from somewhere/ something/ someone + permanently/short time + intentionally
3) Abandon	Leave (a place or vehicle) empty or uninhabited, without intending to return	move away + from somewhere/ something/ someone + intentionally + permanently(forever)

From the above three meanings, we see that the meaning components similar in all three verbs are: direction - move away, source - from somewhere /something / someone, mode - intentionally. Meaning components which are different are: **duration** forever (abandon), for short time / permanently (leave, depart), **mode** - accidentally (leave). Using the method explained above ontological attributes were identified for motion verbs in English. The types and number of subtypes of motion verbs is given in Table 4.

6 Conclusion

Verbs can be searched based on its features and if the particular verb is absent in a language, verbs with neighbouring features can be searched. Feature space will be same across languages. That is, if we know the feature space of verb 'fall' in English, using the same feature space we can obtain the verb 'fall' in Hindi or Sanskrit or any other language. In a sentence if we can identify the feature space of a verb in a particular context[15] then it can be replaced by verb in another language which has similar feature space. Feature space of each verb will be unique. This method will help in resolving a major problem of translation which is identification and translation of verb in a sentence.

[9] http://www.merriam-webster.com/

[10] http://oald8.oxfordlearnersdictionaries.com/

[11] dictionary.reference.com/browse/

[12] http://dictionary.cambridge.org/dictionary/british/

[13] Verbs with similar overlapping verb senses can be differentiated by the ontological attributes were concluded upon by introspection (looking at meanings of verbs in different resources) and based on the concept that there are no synonyms in languages.

[14] http://www.ei.sanken.osakau.ac.jp/main/documents/OnProperty.pdf

[15] A verb can have different meanings. Hence one verb will be placed in different cells in the punct matrix if it has more than one meaning and the feature space of verbs in different cells will be different. So if a verb has two meanings, the feature space of the two verbs will be different.

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Table 4: Feature-space of motion verbs consisting of ontological attribute set

Main Class of Ontological Attributes	**Sub-Attributes**		**Sub-Sub-Attributes**
Space	Direction (linear)	24	(backward, backwards, after, along, through, across, over, back — forth, side to side, forwards, forward, to, towards, from, in front, with, away, further away, behind, in , into, out of, up, upward)[prepositions]
	Direction (down)	1	(down) [prepositions]
	Direction (curvilinear)	3	(around, about, direction-less) [prepositions]
	Path	12	(circle, long way, along a path, direction-less, across a surface, straight line, winding course, zigzag course, long distance, over mountains / hills / forest, over difficult surface , in the direction you want it to move) [locations]
Location	Source	11	(observer, one side of something, position, point, somewhere, line, a fixed point, something, someone , a place , closed place) [locations]
	Object on which acted on	4	(something, someone, own body, group of people) [locations]
	Destination	17	(source of difficulty, source of anger, to somewhere, countryside, person, animal, goal, to a large area, destination, to previous place, to a particular place, to another place, speaker, location near / familiar to speaker, person being spoken to, point, position, lower value, direction-less) [locations]
	Relative position	1	(previous position) [locations]
	Place of action	9	[locations]
Time	Frequency	2	(repeatedly, continuously) [positions]
	Duration	4	(forever, short time , over a period of time, permanently) [adverbs]
Manner	Mode	100	(awkwardly, easily, closely, unwillingly, accidentally, intentionally, carrying load, smoothly, violently, noisily etc.) [adverbs]
	Speed	16	(quickly, very fast, regular(adj) step(v), easy and comfortable speed, very slowly, suddenly, slowly, fast, speed, swiftly, quick, more quickly than normal, very quickly, extremely quickly, moderately fast, rapidly) [adverbs]
Reason	Purpose	7	(hunting, make move, to go in a particular direction or have a particular result, or to allow or cause this, to get information secretly, try to catch or kill them, go where they go, to hold)
	Cause	5	((after)hitting a surface, force, by momentum / force of gravity by outside forces, rebound)
	Because	20	(strike, due to some reason, feeling tired / bored, tired, from danger , from fear, show annoyance, to start new journey, being frightened, playfully, due to injury / pain, for pleasure and relaxation, for pleasure, to escape, to look important, attract attention, old age, to show place to someone, make certain that they arrive safely or that they leave a place as a part of public celebration)
	Effect of(verb) action	1	((leave behind) pain)