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Compensation in Verbal and Nonverbal Communication after Total Laryngectomy

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Abstract

Total laryngectomy is a major surgical procedure with life-changing consequences. As a result of the surgery, the upper and lower airways are disconnected, the natural voice is lost, and patients breathe through a tracheostoma in the neck. Tracheoesophageal speech is the most common speech rehabilitation technique. Due to the lack of air volume, and the amount of muscle tension in the esophagus, some patients may suffer from a hyper- or hypo-tonic voice, resulting in less intelligible speech. To communicate as intelligibly as possible, patients likely adapt their verbal and nonverbal communication to their physical disabilities. The current study aimed to explore the compensation techniques in verbal and nonverbal communication after total laryngectomy focusing on the complexity of grammar and the use of co-speech gestures. We analyzed previously obtained interviews of eight laryngectomized women on the syntactic complexity in speech and the use and type of co-speech gestures. Results were compared with analyses of productions by healthy controls. We found that laryngectomized women reduce the syntactic complexity of their speech, and use nonverbal gestures in their communication. Further research is needed with systematically obtained data and more suitable match-groups.

Index Terms: total laryngectomy, communication, speech, co-speech gestures, grammar, compensation

1. Introduction

Total laryngectomy (TL) is a surgical procedure with life-changing consequences. During surgery, the complete larynx is removed, and the upper and lower airways are disconnected, as shown in Figure 1. TL is the procedure of choice for patients with advanced hypo-pharyngeal or laryngeal cancer, and for patients who suffer from a disfunctional larynx. The most important risk factors for larynx and hypo-pharynx carcinoma are alcohol use and smoking [1, 2]. Worldwide, more than 100,000 patients underwent TL [3], and in the Netherlands, it concerns around 150 people per year [4]. During surgery, the trachea is attached to the skin on the front side of the neck, resulting in a tracheostoma [5]. The patient breathes through the tracheostoma, which influences lung volume, speaking, and swallowing. A disadvantage of this new way of breathing is that the inhaled air is no longer humidified, heated, and filtered through the nose. As a result, patients cough up mucus more often and face complications, including respiratory infections, fatigue, and reduced lung volume [6, 7].

Due to removing of the vocal cords, patients are no longer able to produce voiced speech. There are three options for speech rehabilitation after TL, including using an electrolarynx, esophageal speech, and tracheoesophageal speech [9, 10]. Tracheoesophageal speech is the most used technique and is considered as the gold standard [11, 12]. For this technique, a valve is placed between the trachea and esophagus during a primary or secondary puncture [13]. When the patient occludes the tracheostoma, the airflow goes from the lungs, via the valve, into the esophagus. This airflow brings the esophagus in vibration, creating a new and hoarse sound that allows the patient to speak (see Figure 2).

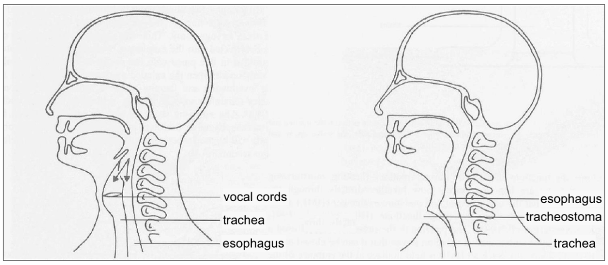

Figure 1: *The anatomical situation before (left) and after (right) Total Laryngectomy.[8]*

Unfortunately, not all patients are able to express themselves intelligibly with the tracheoesophageal voice. Due to the lack of air volume and the amount of muscle tension in the esophagus, some patients may suffer from a hyper- or hypo-tonic voice. It is essential to realize that laryngectomized patients are mentally unharmed and that their problems are caused by their physical limitations. Thus, it might be reasonable to assume that patients adjust their verbal and nonverbal communication to make most of their physical possibilities. For instance, verbal communication can be adjusted by adapting the syntactic complexity by producing less complex or shorter sentences. Nonverbal communication can be increased by using gestures that are produced next to speech and that illustrate (most of the time) the concepts that are conveyed in speech. These gestures are also known as co-speech gestures [14]. Although the literature on this topic is lacking, we hypothesized that patients might adapt their syntactical complexity in speech and use co-speech gestures to support their speech, communication and intelligibility. Knowledge of such compensatory strategies would be helpful to improve speech and language therapy and better inform patients and their loved ones about what to expect after the surgery and how to compensate in communication after the procedure. Therefore, this current study aimed to explore the compensation in verbal and nonverbal communication after TL using the following research questions: (1) Do patients who

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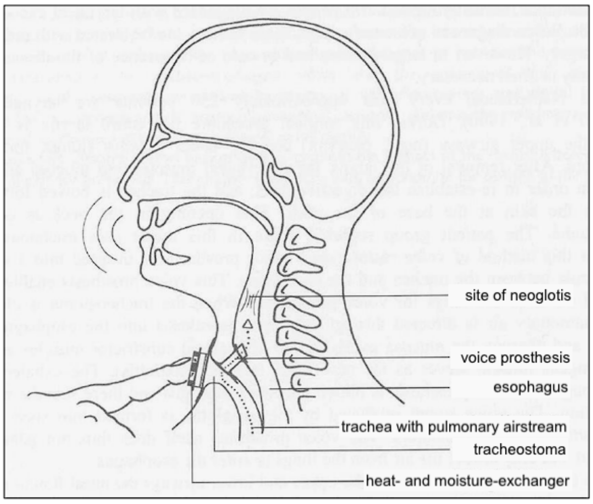

Figure 2: *Tracheoesophageal Speech. The patient occludes the tracheostoma, the air goes from the lungs via the valve into the esophagus, causing vibration and creating a hoarse sound. [8]*

underwent total laryngectomy reduce syntactic complexity, as compared to healthy controls? (2) Do patients who underwent total laryngectomy produce more often co-speech gestures than healthy controls?

2. Methods

The current study is considered as a pilot study and was undertaken at the Department of Head and Neck Oncology and Surgery of the Netherlands Cancer Institute, Amsterdam, the Netherlands. The study was approved by the Institutional Review Board and registered under IRBd20-367.

2.1. Participant Characteristics

2.1.1. Patients

For this study, we used a data-set of video recordings and transcribed interview recordings previously collected by [15]. The interviews were about the perspectives of women on their life after TL. The interviews lasted about 90 minutes. A total of eight laryngectomized patients were included and interviewed by [15]. All patients were female and spoke Dutch as their first language. At the time of the interview, the patients were between 60 and 76 years (M=68; SD=5.9) old and had undergone laryngectomy from 1 to 31 years ago. All patients used tracheoesophageal speech. Seven patients had good intelligibility and were able to speak in fluent sentences. One patient had poor intelligibility and was limited in her verbal communication.

2.1.2. Control group

To compare the syntactic complexity in speech, eight sex-matched controls (age 31-62, M=47; SD=13.8) were included from the IFA Dialog Video Corpus [16]. The control group for the co-speech gestures consisted of four controls who participated in topic-matched interviews from a podcast. Two of four controls were women, and the other two were men (age 24-49, M=37; SD=13.3). Summary data comparing patients and controls are presented in Table 1.

Table 1: *Summary characteristics of patients who underwent total laryngectomy and controls*

	TL patients	**Grammar: Controls**	**Gestures: Controls**
Subjects, *n*	8	8	4
Sex, M/F, *n*	0/8	0/8	2/2
Age, y	68 ± 5.92 (60-76)	47 ± 13.75 (31-62)	37 ± 13.34 (24-49)
Number of years TL	14 ± 10.54 (1-31)		
Education level, *n (%)**			
1	1 (12.5)	0 (0)	0 (0)
2	2 (25.0)	0 (0)	1 (25.0)
3	2 (25.0)	1 (12.5)	0 (0)
4	2 (25.0)	0 (0)	3 (75.0)
5	1 (12.5)	7 (87.5)	0 (0)
Intelligibility			
Poor	1 (12.5)	0 (0)	0 (0)
Good	7 (87.5)	8 (100)	4 (100)

Data are presented as mean ± SD (range), or n (%). TL = Total Laryngectomy
**Education level 1: Lower education, level 2: Secondary education, level 3: Vocational education, level 4: Higher vocational education, level 5: University*

2.2. Syntactic complexity in speech

To explore the syntactic complexity in speech, around 1000 words per patient and control were prepared for analysis and controlled by a second researcher (BvR). Strings of words were labeled as utterances, C-units, clauses, prepositional phrases (PPs), and noun phrases (NPs) [17, 18, 19, 20, 21, 22, 23]. C-units are defined as one main clause with one or more subordinate clauses in oral language [24]. The complexity of C-units were categorised as only main clause (simple C-unit), main clause and one subordinate clause (Complex1), main clause and two subordinate clauses (Complex2), main clause and three or more subordinate clauses (Complex3+). The clauses were divided into reduced (ellipsis or telegram style) and unreduced (a group of words consisting of at least a subject and predicate) clauses. The NPs were split into simple NPs (pronoun, anaphoric determiner or single noun (+ determiner)), compound NPs (coordinating nouns or noun phrases), and complex NPs (one or more nouns with nomical modifiers). The syntactic structures were chosen to investigate, because it was thought that the decreased air volume and maximum phonation time of such persons [25] would most likely affects the syntactic structures and not the morphology or phonology.

Subsequently, the mazes (incomplete clauses, false starts, repetitions, and interjections (words which express a feeling or emotion, like affirmation, denial, uncertainty, and anxiety) were marked and the number of occurrences of the different units in the data-set per participant and per group were counted. After counting, the C-unit complexity ratios, a clause complexity ratio, and an NP complexity ratio were calculated per patient, per control and per group. Other features gathered from the data-set were the percentage of the different types of C-units, clauses, and NPs per subject and per group.

2.3. Annotation and analysis of co-speech gestures

To analyse the use and type of co-speech gestures in the patient and control group, we performed time sampling. The Random Number Generator by Google was used to generate random samples. From every randomly generated point of time, the following 1.5 seconds were analysed on gesture use and type in both groups. To explore the gesture types, we used the co-speech gesture classification of [26]. The classification includes the gesture types Iconic, Metaphoric, Deictic, Beats, Emblems and Butterworths. Iconic gestures represent objects or their attributes, actions, and spatial relations. Metaphoric gestures embodies an abstract idea in a concrete form. Deictic gestures are pointing gestures and Beats keep up the rhythm of speech. Emblems are conventionalised gestures and Butterworths accompany speech failures and word retrieval.

To create an overview of the used gesture types by the patients, a total of 40 minutes (8x5 separate minutes) per interview

Table 2: *Outcomes on mazes in speech of patients and controls*

Part.	Total #words	Incomplete clauses		False starts		Repetitions		Interjections		Total words in mazes	
		#	#words	#	#words	#	#words	#	#words	#	%
PT1	1010	3	7	11	23	0	0	39	41	71	7.0
PT2	1013	1	3	4	4	2	3	43	45	55	5.4
PT3	1000	4	7	3	8	2	3	44	45	63	6.3
PT4	1021	10	29	5	13	3	5	42	48	95	9.3
PT5	1013	6	22	10	29	1	2	33	36	89	8.8
PT6	1002	9	30	13	32	3	4	36	36	102	10.2
PT7	1015	6	18	13	34	8	11	88	93	156	15.4
PT8	1003	3	3	7	10	0	0	66	67	80	8.0
PTM (SD)	**1010 (7)**	**5.3 (3.1)**	**14.8 (11.3)**	**8.3 (4.0)**	**19.1 (11.8)**	**2.4 (2.6)**	**3.5 (3.5)**	**48.9 (18.7)**	**51.4 (19.5)**	**88.9 (31.5)**	**8.8 (3.1)**
C1	1038	15	51	11	28	32	52	39	39	170	16.0
C2	1012	5	11	17	35	32	40	79	82	168	16.6
C3	1019	5	14	15	30	13	17	76	85	146	14.3
C4	1040	8	20	14	27	24	46	48	51	144	13.8
C5	1013	4	16	11	20	7	7	89	95	138	13.6
C6	1051	6	12	23	49	33	44	122	129	234	22.3
C7	1052	7	24	20	61	16	25	72	82	192	18.3
C8	1001	6	26	13	25	14	20	49	66	137	13.7
CTM (SD)	**1028 (19)**	**7.0 (3.5)**	**21.8 (13.0)**	**15.5 (4.3)**	**34.4 (19.8)**	**21.4 (10.1)**	**31.4 (16.2)**	**71.8 (26.9)**	**78.6 (27.6)**	**166.1 (33.4)**	**16.1 (3.0)**

PT: Patient, C: Control, PTM: Patient Total Mean, CTM: Control Total Mean, SD: Standard Deviation

were annotated. The five separate minutes in which the patients appeared to produce the most co-speech gestures were annotated using the software program ELAN [27]. The number of produced co-speech gestures was determined, and the type of the gestures was classified and counted.

2.4. Statistical analysis

To explore the syntactic complexity in tracheoesophageal speech and the use and type of co-speech gestures during speech, descriptive statistics were used. To compare the outcomes of patients with controls, data was analyzed using the non-parametric Mann-Whitney U test followed by a Bonferroni correction to control for Type 1 errors with multiple testing [28]. A Bonferroni-adjusted value of $P \leq .003$ was regarded as statistically significant. All data was analyzed using [29].

3. Results

3.1. Syntactic complexity in speech

The patient group produced fewer dysfluencies than the control group, while the typical length of each disfluency, counted in words, was almost identical per disfluency type (see Table 2). On average the controls produced twice as many false starts (M=15.5; SD=4.3) as the patients (M=8.3; SD=4.0), with lengths of 2.22 and 2.18 words per false start respectively. The control group produced vastly more repetitions (M=21.4, SD=10.1) than the patients (M=2.4, SD=2.6), again of roughly similar length of 1.42 and 1.57 words per repetition respectively. The control group also produced many more interjections (M=71.1, SD=26.9) than the patient group (M=48.9, SD=18.7), but of similar length at 1.10 and 1.05 words per interjection respectively. Taken together, the control group uttered an average of 16.1% (SD=3.0) of their words in mazes, in comparison to the 8.8% (SD=3.1) of the patient group. A Mann-Whitney U test showed that the patients and controls differ significantly from each other in the percentage of words in mazes (U=4, Z=-2.9, *P*=0.002**) (see Table 3).

The average syntactic units were consistently shorter in the patient group than the control group (see Table 3). The average C-unit, a main clause with its dependent clauses, was more than a word shorter in the speech of the patient group than the control group. The patient group had an average of 6.4 words (SD=0.9) per C-unit, while the control group averaged 7.5 words per C-unit (SD=0.8). This difference was significant, as established by a Mann-Whitney U test: U=10.5, Z=-2.2, P=0.014*). The NP complexity ratio, the number of words per noun phrase, is lower for the patient group than for the control group. Patients had an average NP of 1.5 words (SD=0.1), while the controls had

Table 3: *Overview of the means, standard deviations and the Mann-Whitney U test on the mazes and syntactical complexity measures of patients and controls*

Measure		***Patients***		***Controls***		***Mean Diff (M-W)***		
		Mean	*SD*	*Mean*	*SD*	*U*	*Z*	*P*
C-unit complexity ratio 1 (words/C-unit)		6.4	0.9	7.5	0.8	10.5	-2.2	0.014*
C-unit complexity ratio 1 (clauses/C-unit)		1.2	0.1	1.2	0.1	19	-1.3	0.095
Types of C-units	*%Simple*	84.5	5.7	81.1	5.8	7.5	2.5	0.006*
	%Complex1	13.2	4.1	15	3.3	27	0.5	0.312
	%Complex2	1.7	1.4	2.9	2.0	24	-0.8	0.215
	%Complex3+	0.5	0.5	0.9	1.1	27.5	-0.4	0.337
Clause complexity ratio		5.4	0.5	6.1	0.5	7	-2.6	0.005*
Types of clauses	*%Unreduced*	86.8	8.3	85.4	4.5	4	2.9	0.002**
	%Reduced	13.2	8.3	14.6	4.5	32	0.1	0.480
NP complexity ratio (words/NP)		1.5	0.1	1.7	0.1	1	-3.2	0.001**
Types of NPs	*%Simple*	92.3	1.7	85.6	4.1	4	2.9	0.002**
	%Compound	0.7	0.4	1.5	0.6	12	-2.0	0.020*
	%Complex	7.0	1.6	13	4.5	8	-2.5	0.007*
%Mazes		8.8	3.1	16.1	3.0	4	-2.9	0.002**
Types of mazes	*Interjections*	48.9	18.7	71.1	26.9	12.5	-2.0	0.023*
	Repetitions	2.4	2.6	21.4	10.1	1	-3.2	0.001**
	False starts	8.3	4.0	15.5	4.3	6	-2.7	0.004*
	Incomplete clauses	5.3	3.1	7.0	3.5	22.5	-0.9	0.171
	Total words mazes	88.9	31.5	166.1	33.4	4	-2.9	0.002**

*We used the Mann-Whitney U Test, one-tailed, with an alpha of 0.05. *Statistically significant P≤0.05, **Statistically significant after Bonferroni correction P≤0.003.*

Table 4: *Means and standard deviations of the use and type of co-speech gestures in patients and controls in the time samples*

		Patients			Controls		
		Total	Mean	SD	Total	Mean	SD
Gesture type	*Iconic*	9	1.1	0.8	2	0.5	1.0
	Metaphoric	0	0	0	0	0	0
	Deictic	8	1	1.4	0	0	0
	Beats	19	2.4	2.1	18	4.5	1.9
	Emblems	10	1.3	1.2	2	0.5	0.6
	Butterworths	0	0	0	0	0	0
	Total	**46**	**5.8**	**2.1**	**22**	**5.5**	**1.3**

an average of 1.7 words per NP (SD=0.1). A Mann-Whitney U test showed that the patients and controls differ significantly from each other in the number of words per NP (U=1.0, Z=-3.2, P=0.001**).

3.2. Co-speech gestures

Eighty randomly chosen time samples (10 x 8 interviews x 1.5 seconds) of the patients and forty samples (10 x 4 interviews x 1.5 seconds) of the controls have been analyzed. In the patient group, co-speech gestures have been observed 46 times versus 22 times in the control group. In the time samples, the patient group produced an average of 5.8 co-speech gestures (SD=2.1), while the control group averaged 5.5 co-speech gestures (SD=1.3) (see Table 4). This means that the patient group produced one co-speech gesture per 2.6 seconds versus one co-speech gesture per 2.7 seconds in the control group.

The gesture type Beats was produced the most frequent in both groups. We found an average of 2.4 Beats gestures (SD=2.1) in the patient group, compared to 4.5 Beats gestures (SD=1.9) in the control group. The second most produced gesture type were Emblems, with an average of 1.3 gestures (SD=1.2) and 0.5 gestures (SD=0.6) respectively. The gesture types 'Metaphoric' and 'Butterworths' were not observed during the time samples, not in the patient group, nor in the control group (see Table 4).

Within the fully annotated 40 minutes of the interviews with the patients, 609 co-speech gestures were observed. Meaning that patients, on average, produce one co-speech gesture every 3.94 seconds. The top three most frequently used gesture types were Beats, with a total of 272 gestures observed (M=34.0, SD=11.6), followed by the type Iconic with an amount of 136 gestures (M=17.0, SD=5.9) and thirdly, the type Deictic with a total of 105 gestures (M=13.1, SD=4.7) produced by patients. Butterworths were observed the least with a total of four gestures (M=0.8, SD=0.) (see Table 5).

Table 5: *Types of co-speech gestures observed in patients during the annotated 40 minutes of the interviews*

		Patient								**Total**	**Mean**	**SD**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**			
Gesture type	*Iconic*	22	14	12	8	25	16	23	16	**136**	17.0	5.9
	Metaphoric	0	0	4	1	0	0	0	1	**6**	0.8	1.4
	Deictic	10	16	11	23	8	14	13	10	**105**	13.1	4.7
	Beats	20	27	44	42	33	24	28	54	**272**	34.0	11.6
	Emblems	10	3	7	10	12	4	23	17	**86**	10.8	6.7
	Butterworths	1	0	0	1	2	0	0	0	**4**	0.5	0.8
	Total	**63**	**60**	**78**	**85**	**80**	**58**	**87**	**98**	**609**	76.1	14.4

4. Discussion

This preliminary study explored the syntactic complexity in tracheoesophageal speech and the use and type of co-speech gestures during speech in eight laryngectomized women compared with healthy controls.

4.1. Syntactic complexity in speech

Mutually reinforcing patterns emerge from the analysis of disfluencies and syntactic complexity. Patients display fewer disfluencies: false starts and repetitions, and also interrupt for less often than the control group. This suggests that they spend more time planning what to say and when to say it, whereas the cost of less extensive planning is not so high for the control group and they therefore allow themselves the luxury of reformulations. Interruptions are more frequent than disfluencies for the patients too, but they nevertheless interrupt less often than the healthy control group. They attempt to maintain aspects of interactive communication, but do not interact as often and remain more guarded than the healthy controls.

The patient group's syntactic complexity measures point to shorter units, both in terms of ideas (C-units) and at referential level (NPs). Their expressions are more condensed; they expend less speech effort than the control group. Given that there is no difference in cognitive functioning, the complexity measures also point to more careful planning in order to say things in less elaborate ways. Both analyses thus add up to support a picture of more carefully planned speech and less interactivity. This finding can be attributed to the fact that controls have a larger air volume and a longer maximum phonation time than patients [11]. Another reason why patients seem to be more careful in planning is that they might feel less confident and try to avoid the effort of repair strategies. In comparison, controls do not seem to care about mazes, as it is not much of an effort for them. Furthermore, controls have a more extended breath than patients, which enables them to utter longer C-units than patients. Patients require more planning for the physical act of speech, given the coordination of breathing and physical closing of the valve, hence it is not so easy to engage in short interactive exchanges. They are nevertheless able, in lower frequencies, to maintain some of the markers of informal interactive speech.

4.2. Co-speech gestures

The patients in this study seem to make an effort to make co-speech gestures, in a comparable amount of the controls. During the random time sample, patients used one co-speech gesture per 2.6 seconds, whereas the control group produced one co-speech gesture per 2.7 seconds. Our findings do not correspond with the findings of [30] who found that healthy participants used one gesture every 16.04 seconds. The difference could be explained by the task the participants were asked to perform. In [30] the participants were asked to give driving directions to one another, whereas our patients and controls were interviewed. Another explanation could be the differences in participant characteristics. [30] included young male students, and in our study we included laryngectomized women with a mean age of 68, and controls with a mean age of 37. During the annotation of 40 minutes of the interviews, the patients produced one co-speech gesture every 3.94 seconds. Although we searched especially for five separate minutes in which the patients seemed to produce the most co-speech gestures, the production of gestures is slightly lower than the production of one gesture per 2.6 seconds that we found during the time sample. Focusing on gesture types, Butterworths gestures were least observed during the annotation. [26] defined Butterworths as gestures that accompany speech failure, that occur as part of an effort to recall or find a word. The results about the mazes (see Section 4.1) can explain the small amount of Butterworths gestures that we found in the patients. As stated before, patients plan their speech more carefully and produce fewer mazes than controls. Therefore, they might not need Butterworths gestures. It is important to keep in mind that patients were only able to use one hand while they spoke. The ability to use only one hand for gesticulation could influence the frequency of gesture use. However, the results show a fair amount of co-speech gestures used by the included patients in comparison with the controls, which may indicate that patients consider gesticulation important in their communication.

4.3. Limitations and future research

This study has several limitations that will be addressed in future investigations. Most notably, the re-used interviews of patients that served as our database had not been collected for the aim of this study. The angle of the video recordings differs per interview. Second, the control groups did not perfectly match the patient group. The control groups had lower ages and higher educational levels than the patients. Furthermore, the control group for co-speech gestures consists of four (famous Dutch) persons who might have been trained for public speaking.

Recommendations for further research would be to collect data systematically by giving the patients and controls the same task to provoke (semi)spontaneous speech, and to use gender-, age and educational matched groups.

5. Conclusions

To our knowledge, this is the first study exploring the compensation in verbal and nonverbal communication strategies of laryngectomized patients (women) focusing on the syntactic complexity in speech and the use and type of co-speech gestures compared with controls. This study found indications that patients use different techniques to compensate for their physical disabilities. Firstly, patients seem to be a bit more certain and careful in planning an utterance. Secondly, patients appear to reduce their syntactic complexity of utterances and, lastly, they seem to use co-speech gestures to support their verbal communication. Further research is needed with systematically obtained data and more suitable match-groups.

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